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Science and Service

It is evident that the great masses of humanity have yet to be educated in the scientific method of thought and action. All scientific men and women may do their bit—*first*, by training themselves to observe accurately, to think straight, and then to record clearly and honestly, and to draw warranted conclusions based on the facts presented, "free from previous preconception and prejudice;" *second*, by reviewing the mass of technical information with which they are familiar and telling the story they have learned in simple, clear language, free from obscure, complicated, technical, and verbose wording. These simple suggestions apply not only to research workers in science, but to all the professional classes as well, theologians, doctors, lawyers, statesmen—especially lawyers and politicians, and of course professional teachers in schools and colleges.

CHARLES D. WALCOTT

(Excerpt from address before the American Association for the Advancement of Science)

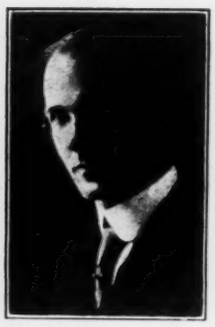
AUGUST 1925

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

R. J. Anderson

A. J. T. Taylor

J. H. Polhemus



A. G. Christie

D. A. Morrow

W. J. Wohlenberg

Contributors to this Issue

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* * * * *

M. L. Dodge is chief engineer with the Seattle-Astoria Iron Works, Seattle, Wash. He took the mechanical engineering course at Rose Polytechnic Institute for two years. In 1907 he went to the Pacific coast as chief draftsman with the McConnell Engineering Co. In 1911 he became connected with the Ajax Auto Traction Co., resigning to become chief draftsman of the Willamette Iron & Steel Works, Portland, Ore. Since 1915 Mr. Dodge has been with the Seattle-Astoria Iron Works.

* * * * *

Solomon Einstein has been connected with the Cincinnati Milling Machine Co. since 1904, where he has held various positions in their engineering department. Since 1920 Mr. Einstein has been chief engineer for the company. He was educated at the Technical University at Darmstadt and came to this country in 1903.

* * * * *

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* * * * *

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* * * * *

Walter J. Wohlenberg is assistant professor of mechanical engineering at Yale University. He was graduated from the University of Nebraska in mechanical engineering in 1910, and after two years with the Westinghouse Machine Co., engaged in engineering research at the University of Illinois. In the fall of 1914 he became assistant professor of mechanical engineering at the University of Oklahoma, where he taught two years. The next two years were spent in a similar capacity at the University of Montana. Since 1918 he has been at Yale.

* * * * *

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* * * * *

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* * * * *

Robert J. Anderson is a consulting metallurgical engineer in Pittsburgh, Pa. He received his B.Sc. in metallurgy from the Case School of Applied Science in 1914, his Met.E. in 1914, and in 1925 a D.Sc. from the Massachusetts Institute of Technology. He served for one year as instructor in metallurgy in the Missouri School of Mines and then became chief metallurgist of the Cleveland Metal Products Co. During 1918 Mr. Anderson was research metallurgist with the Bureau of Aircraft Production, and was then appointed metallurgical engineer in charge of the non-ferrous metals section of the U. S. Bureau of Mines, Pittsburgh, Pa., where he remained until 1924.

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* * * * *

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* * * * *

R. A. Bull is a director of the Electric Steel Founders' Research Group in Chicago. He received his A.B. from Butler College in 1897 and his M.A. from St. Louis University in 1914. Mr. Bull worked as an inspector for Robert W. Hunt & Co. in Chicago, the U. S. Cast Iron Pipe and Foundry Co., Bessemer, Ala., the Water Department of the City of Louisville, Ky., and the Shickle, Harrison & Howard Iron Co. in East St. Louis, Ill. Later he held positions of importance with the Leighton & Howard Steel Co., the American Steel Foundries, the Commonwealth Steel Co., the Chicago Steel Foundry Co., and the Duquesne Steel Foundry Co.

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The Diesel-Electric Pipe-Line Dredge "Clackamas"

Details of the Port of Portland's 30-In. Hydraulic Dredge, the Largest yet Constructed, and the First of the Type to Use Diesel-Electric Power

By JAMES H. POLHEMUS,[1] PORTLAND, ORE.

THE dredging operations of the Port of Portland cover a wide range of conditions as to material excavated, location of the dredged area, depth of water desired, length of discharge pipe, terminal lift, distance of the area to be dredged from the source of fuel supply, etc. Dredging experience in the district with publicly maintained equipment dates from 1898, and study of the applicability of the pipe-line dredge has been featured the last few years by the adoption of mechanical changes which reached a high stage of development with the design of the Diesel-electric dredge built in 1925.

The various kinds of material dredged—heavy gravel, blue clay, sawmill trash, sharp sand, fine silt, or a mixture of all—call for changes in cutter speed, pump speed, and swinging speed as well as change in power. In some locations efficiency calls for a long radius of swing and a deep reach of ladder, also strong spuds. Other locations, such as narrow areas in pier slips, require limited breadth and compact hull outlines. In very shallow digging it is necessary to use a specially designed ladder.

The available discharge basin may demand a long discharge pipe and maximum terminal lift, or a short pipe line and nominal lift.

From a consideration of all conditions which have been encountered in the past or anticipated as to the future, including the possible reoccurrence of a shortage in hog fuel, the port engineers decided upon the use of Diesel engines of high power on account of their marked operating efficiency, full dependability, and economy as compared with steam power.

To meet the changing dredging conditions it was necessary that the speeds of the dredging pump, cutter motor, and swinging motors be adjustable to the highest degree. It was desirable that the equipment should be as simple, reliable, rugged, and flexible over a wide range of conditions as possible. These considerations demanded transforming the power of the Diesel engines into electrical energy.

After a thorough investigation it was decided that direct-current equipment was particularly well suited to meet the special conditions under which it is intended this dredge will be operated.

One desirable feature of the system selected is that direct-current machinery is well understood by most engineers and operators, so that it can be left in the hands of men of average ability and training and not require the services of a highly trained technical expert.

That the description of the dredge *Clackamas* which follows may be better understood, brief reference will be made to two modern 30-in. steam-operated pipe-line dredges at present in use by the Port of Portland, namely, the *Columbia* and the *Tualatin*.

The *Columbia* is a steel dredge 236 ft. long, of 44 ft. beam and 11 ft. 8 in. in depth; its draft is 6 ft. 8 in. and it displaces 1820 tons. The dredging pump is a plate-steel-lined slow-speed pump driven by a 1500-i.hp. 4-cylinder triple-expansion engine at from 160 to 200 r.p.m. This dredge has a capacity of about 20,000 cu. yd. of sand per day, and operates satisfactorily with pipe lines not exceeding 2500 ft. in length with a terminal lift of 30 ft.

The *Tualatin*, constructed in 1915, has a steel hull of the same dimensions as the *Columbia*, but her displacement is 50 tons less, due to the use of steam turbines and higher speed of operation. The dredging pump is a plate-steel-lined high-speed pump driven by a 2000-s.hp. steam turbine through gear reduction at 300 r.p.m. This dredge has pumped through 8000 ft. of pipe line. On long pipe lines and over an extended period the *Tualatin* has handled on the average from 30 to 50 per cent more material than the *Columbia*, due chiefly to the increased power of the pumping unit.

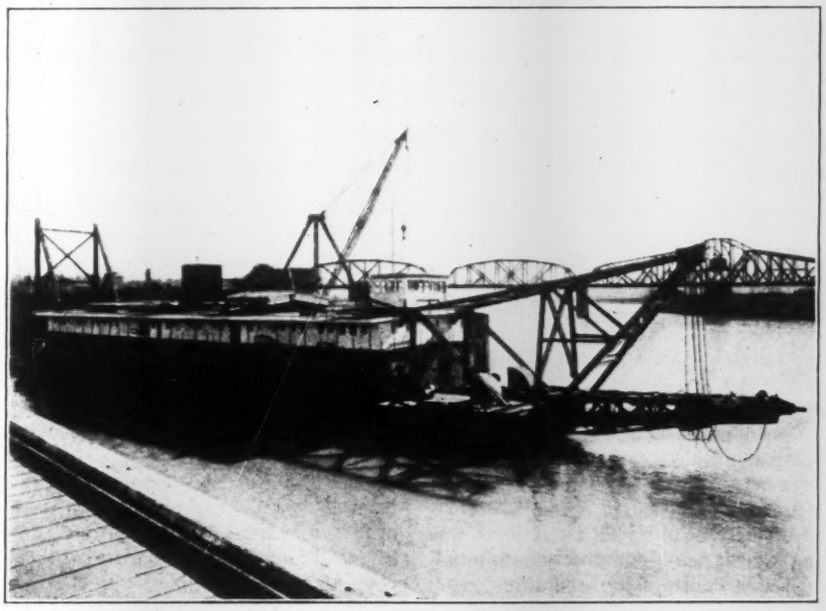

FIG. 1 THE DREDGE "CLACKAMAS" AT DOCK

THE HULL OF THE DREDGE "CLACKAMAS"

The dredge *Clackamas*, Figs. 1 and 2, is built of steel, and is 236 ft. long, of 50 ft. beam, and 12 ft. 9 in. deep, and will at 7 ft. 8 in. draft displace 2480 tons. This displacement includes a week's supply of fuel oil, potable water, and perishable commissaries a month's supply of staple commissaries, a three months' supply of lubricating oil, engine stores, and spare parts for pump and pipe line. It is 37 per cent greater than that of the dredge *Columbia*, because of the greater power on the new dredge.

The *Clackamas* will have 2700 shaft hp. at the dredging pump, which is approximately 90 per cent greater than that of the dredge *Columbia* (1500 i.hp.) and 35 per cent greater than that of the dredge *Tualatin* (2000 s.hp.).

In an emergency the *Clackamas* has tankage for 3948 bbl. of fuel oil, more than two months' supply under probable working con-

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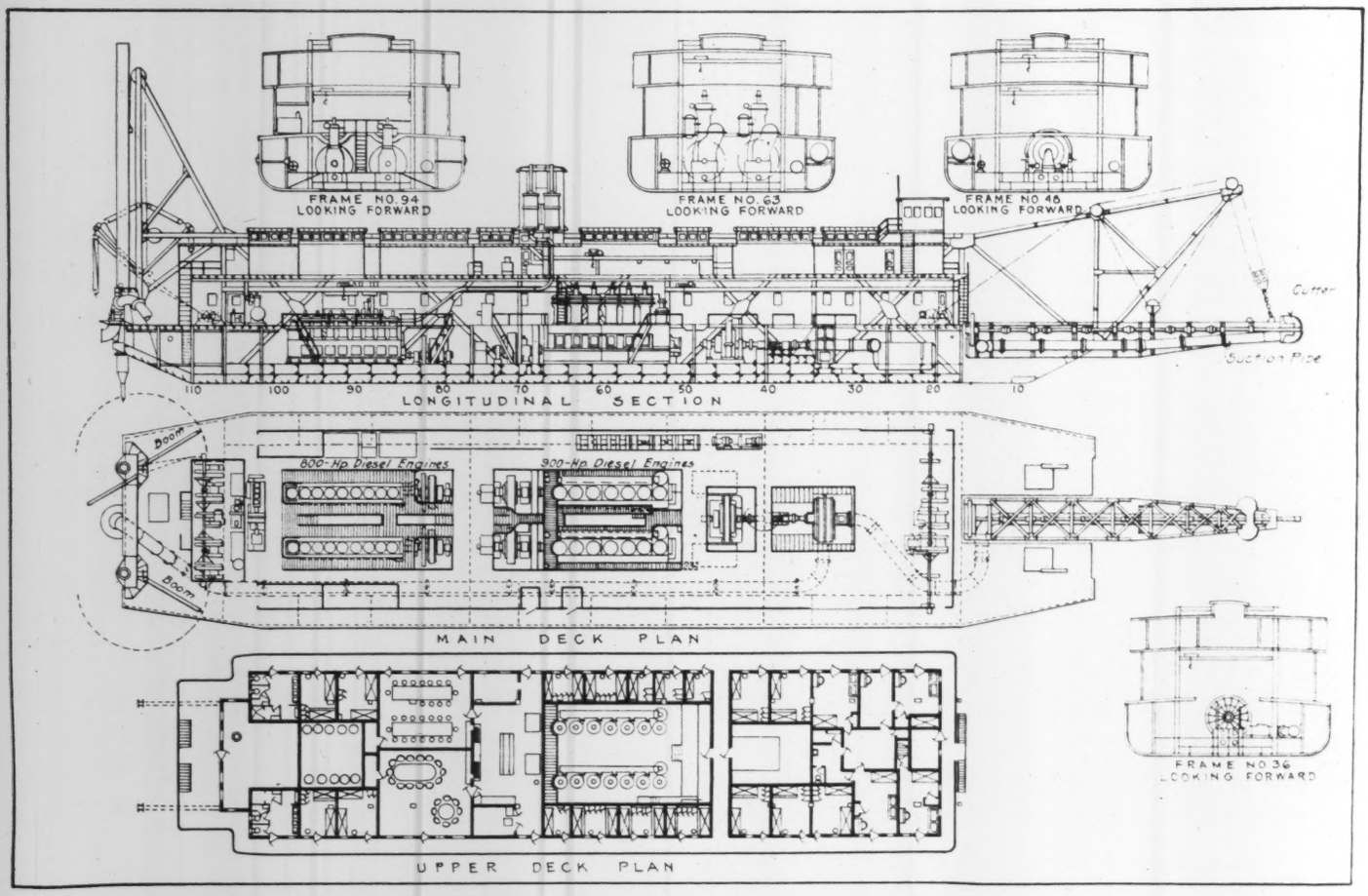

FIG. 2 GENERAL ARRANGEMENT OF THE DIESEL-ELECTRIC DREDGE "CLACKAMAS"

ditions of 66 per cent of time at full power. Tankage is provided for 29,954 gal. of potable water, more than three weeks' supply, and for 7702 gal. of lubricating oil, more than seven months' supply. Under these conditions the hull would have 21 in. increased draft, leaving 3 ft. 4 in. freeboard.

It was desired that the *Clackamas* should be kept as compact as possible. For that reason the hull was made the same length as the *Columbia's* but 6 ft. wider and 1 ft. deeper.

The spud wells are placed at the aft end on the *Clackamas*, which gives it 20 ft. greater radius of action than the *Columbia*.

The *Columbia* with a fuel barge alongside is some 29 ft. wider than the *Clackamas*. The *Clackamas* occupies less sea room than any of the other dredges, with a gain in radius of action of 20 ft.

Increasing the displacement by increase of breadth and depth was the most economical method as regards use of construction material, saving in labor and increasing the strength of the structure.

THE LONGITUDINAL BULKHEADS

On each side of the hull, located 7 ft. inboard from the shell plating, is a longitudinal watertight bulkhead extending from the forward athwartship bulkhead (well bulkhead) to the after athwartship bulkhead some 188 ft. in length; this strengthens the hull and particularly strengthens the bottom to offset stresses in case of grounding. The space between this bulkhead and the side of the hull is divided by athwartship partitions or bulkheads into six watertight compartments on each side of the ship.

In case of a side collision the probability is that the damage would not extend through 7 ft. of steel plating, two heavy oak fender strakes, stringers, etc., to the bulkhead; thus only one or perhaps two of the compartments would be flooded, with no danger of sinking the dredge. The Port has had three dredges sunk: two from being rammed by steamers and one by the bursting of the discharge pipe.

These watertight compartments are used for storage of fuel oil, Diesel oil, lubricating oil, and potable water, thereby saving space which otherwise would be taken up by separate tanks, as well as conserving as to their weight and cost.

In the event of sinking it would be possible to blow the water out of these side compartments with air and gain a buoyancy of 1000 tons, which would be of material assistance in floating the dredge and would also save in labor and expense.

THE TRANSVERSE BULKHEADS

There are four transverse watertight bulkheads dividing the hull into six compartments. The forward bulkhead is located at the after end of the ladder well (32 ft. back of the bow) and is the aft bulkhead of a compartment on each side of the well. The second bulkhead is 48 ft. aft of this bulkhead and is placed between the dredging pump and the pump motor. The third bulkhead is 72 ft. back of the second bulkhead and is placed between the forward set of 900-hp. engines and the aft set of 800-hp. engines (Fig. 4). The fourth bulkhead is 60 ft. aft of the third bulkhead, leaving a stern compartment 24 ft. long.

These bulkheads strengthen the dredge through being placed between the different main machinery units and thoroughly tying the machinery keelsons to the longitudinal bulkheads and the sides of the hull. In addition there is a heavy frame 4 ft. 2 in. deep tied to each panel point of the truss, extending to the longitudinal bulkheads and the sides of the hull, with additional deep frames 6 ft. apart tied to the longitudinal bulkheads.

It will be noticed that the aft engines and their generators are in one compartment. The forward engine and their generators and the main pump motor are in another compartment and the main dredging pump is in a separate compartment. Should the bottom of the dredge be injured, causing the filling of any one of the compartments, the damage would be local and affect the electrical equipment in that compartment only. Similarly, should a hull pipe or the dredging pump be ruptured from any cause, the damage would be limited to the compartment where the injury occurred.

THE LONGITUDINAL TRUSS

There is a heavy bridge-type steel truss extending the full length of the hull, the forward end being extended to form the A-frame

for the ladder hoist, and the spud masts aft being tied into and forming a part of the truss. This truss also carries the crane runway girders.

This truss, Fig. 5, is calculated to support the weight of the dredge in case of grounding on the two ends. Each of the two side trusses is located one-half the distance from the center line of the dredge to the side plating of the hull. There is ample space between the truss and the longitudinal bulkhead for a passageway and auxiliary pumps on the port side, and for the hull pipe and passageway on the starboard side.

The panel points are spaced 36 ft. apart and the angle of the diagonal members is approximately 45 deg. Forward of the deck house the top member of the truss converges, meeting the forward member of the A-frame 32 ft. forward of the bow. At this location a structural-steel frame is formed carrying five sheaves for the ladder hoist tackle, the lower member of which consists of a quadruple sheave block chained to the digging ladder near the outer end. The after end of the truss is built into the spud-well frames and spud-mast frames. The spud masts are sufficient in height to accommodate the 80-ft. steel spuds and so designed that they may be used to unship or ship a spud in case of breakage.

FIG. 3 CONSTRUCTION DETAILS OF STEEL HULL OF THE DREDGE "CLACKAMAS"

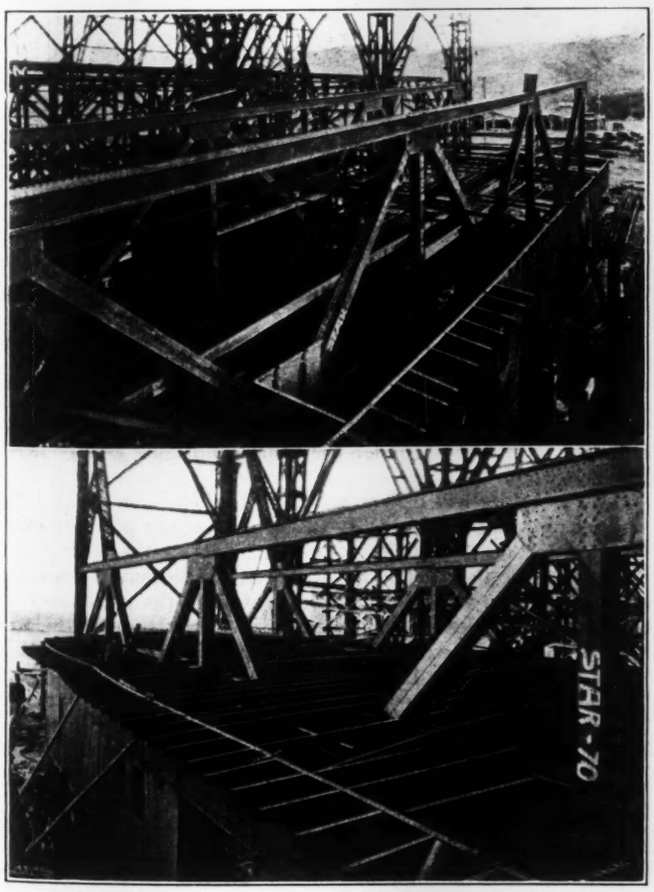

FIG. 5 FORWARD AND AFT PORTIONS OF BRIDGE-TYPE STEEL TRUSS EXTENDING ENTIRE LENGTH OF HULL

FIG. 4 TRANSVERSE BULKHEAD AND COMPARTMENT FOR 800-HP. ENGINES

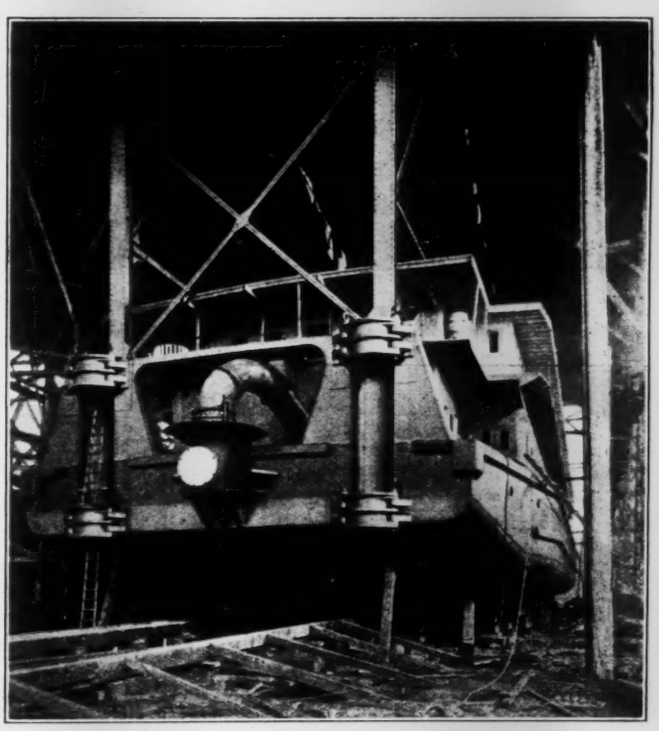

FIG. 6 SPUD WELLS AND KEEPERS

THE SPUDS

Each spud is 35 in. in diameter and 80 ft. long, constructed of $^3/_4$-in. steel plates rolled into a cylindrical tube. There is a hollow cast-steel conical point at the bottom for setting into the bed of the river. There are 14 flanged diaphragm plates riveted to the shell, spaced about 5 ft. apart throughout the length of the spud, which keep the spud from buckling under a beam strain. Constructed in this manner, these steel spuds have double the strength of timber spuds of the same size and are easily repaired or rebuilt in case of injury.

The spud wells (Fig. 6) are placed at the stern and constructed with heavy cast-steel hinged keepers to enable the spuds to be re-

moved should they become bent. The dredge crew with the equipment aboard can readily replace a damaged spud.

Considerable trouble has been experienced with spuds broken by ships bumping the dredge, by shocks due to cave-ins on the ladder, thrusting the dredge back, by the action of the elements in case of storms, etc. On the other dredges, which were designed with spuds in wells through the hull, when a spud is broken it necessitates laying up the dredge for several days. It must be towed to the most available shear legs to install the new spud, entailing lost time as well as cash outlay.

The Main Engines

The main installation consists of two 800-b.hp. McIntosh & Seymour Diesel engines each direct connected to a 540-kw. d.c. generator, and two 900-b.hp. McIntosh & Seymour Diesel engines, each direct connected to a 610-kw. d.c. generator (see Figs. 7 and 8).

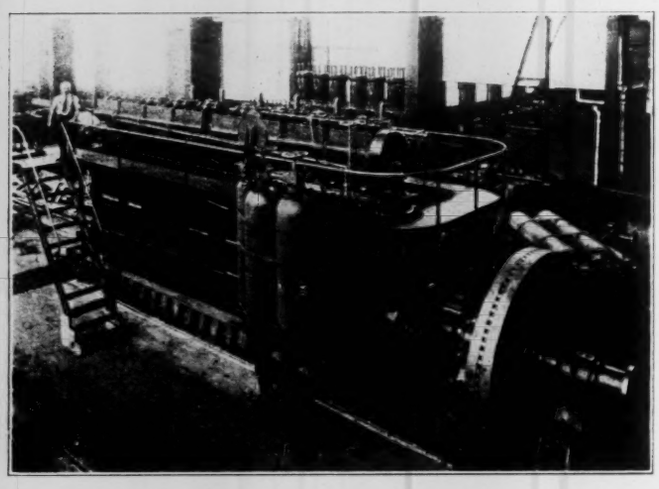

Fig. 7 Shop View of One of the 800-Hp. Eight-Cylinder McIntosh & Seymour Diesel Engines Installed on Dredge "Clackamas"

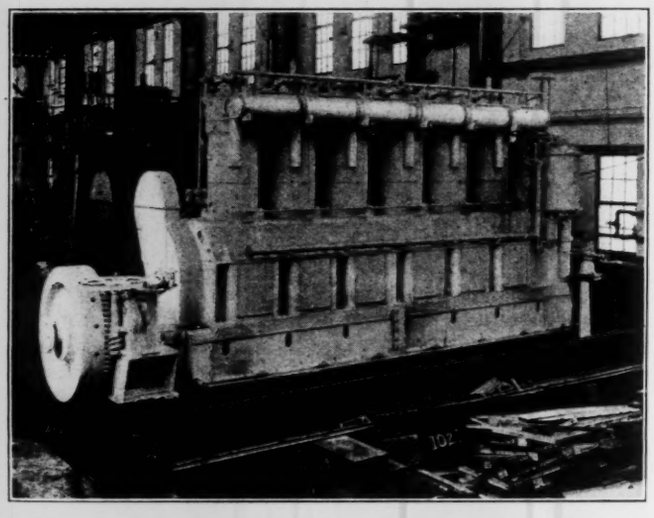

Fig. 8 Shop View of Exhaust Side of One of the 900-Hp. Six-Cylinder McIntosh & Seymour Diesel Engines Installed on Dredge "Clackamas"

It would have been more satisfactory (from any point of view) to have had all the main engines alike, but several years ago the Port of Portland had an opportunity to purchase two 900-hp. engines from the United States Shipping Board at an extremely low figure. Realizing that they would soon be in the market for power equipment on account of their increased activities and knowing the remarkable fuel efficiency of the Diesel engine, they bought these engines. A short time later their 20-in. dredge *Portland* was sunk, with such damage to the hull and machinery (nearly obsolete from age and type) as to require prohibitive expense for repairs or rebuilding. About this time the Guild's Lake project was being considered, and this required long discharge-pipe lines. The remaining dredges of the fleet were of the 30-in. size with most of the equipment, such as ladders, pipe lines, pontoons, cutter heads, etc., interchangeable.

The necessity of increasing the dredging fleet and the desirability of standardizing the equipment as far as possible, determined the design of a 30-in. dredge. The inadequacy of these two Diesel engines to supply enough power for the type of dredge required, necessitated the purchase of the two 800-hp. units. The dredge *Clackamas* was designed to fit these assembled units.

The 800-b.hp. engines are 8-cylinder units of the 4-cycle trunk type, and each at full power turning 200 r.p.m. will consume 1 bbl. of fuel oil per hour. The 900-b.hp. engines are 6-cylinder units of the 4-cycle trunk type, and each at full power turning 150 r.p.m. will consume $1^1/_8$ bbl. of fuel oil per hour.

The combined power is 3400 b.hp. and the total consumption of fuel oil is $4^1/_4$ bbl. per hour (full power) or 102 bbl. per day of 24 hours. However, the average pumping time will probably not exceed 20 hours per day, which would require the consumption of about 85 bbl. per day.

The estimated cost of operating the *Clackamas* as compared to that of our other dredges promises marked saving. Hog fuel, the chopped-up waste from sawmills, is very low priced at present. Considering the cost of hog fuel on barges at the side of the dredge compared with fuel oil under the same conditions greatly favors the new dredge.

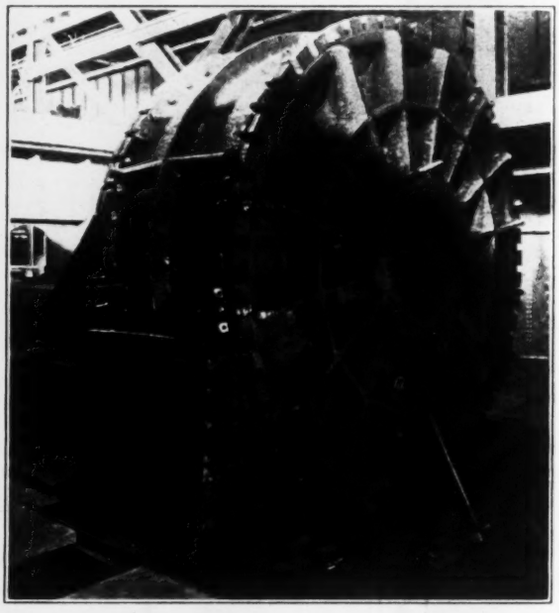

Fig. 9 View of Dredging Pump of Dredge "Clackamas" Showing Suction and Discharge Openings

(Note foundation plate with watertight margin to keep sand and trash out of bilge while cleaning pump when suction is plugged.)

The *Clackamas* will deliver power to the dredging pump (after losses of electric conversion) at 72 per cent of the cost per horsepower on our other dredges, without considering the labor cost of transferring the hog fuel to the furnaces. Considering the delays for cleaning fires, wages of fire-room crew, and the power required for steam auxiliaries—which at times is 42 per cent of the total power as compared with that for electric-driven auxiliaries, which will be between 10 and 15 per cent—the economy of a Diesel-electric dredge is more evident. Using fuel oil under boilers on our other dredges—which has been necessary during a shortage of hog fuel—the cost per horsepower at the pump is more than four times what it is on a Diesel-electric dredge.

The engine power being in four units, the total weight of the plant is reduced; and the electric generators, because of the higher rotative speed, are smaller, which reduces the size of spare parts and makes it easy to handle any repairs that may become necessary, many of which could be taken care of with the shop equipment on the dredge and by members of the dredge crew.

Having four units, it is possible to stop one and obtain approximately 80 per cent efficiency with the remaining three; thus a breakdown of one unit would not seriously hinder the operation of the dredge. On short pipe lines it might at times be advisable to shut down one or more of the engines.

It being necessary to periodically overhaul a Diesel engine, the installation of four large engines makes it possible to shut down one engine for overhauling without interfering with the operation of the dredge. However, it is planned to do this overhauling when dredging conditions are suitable for the operation of three of the main engines. Our steam dredges at times stop work for several weeks to be given a general overhauling. From considerations of safety the four-unit power distributes the weight over a large space, lessens local strains, and reduces vibration by breaking the unison of the moving parts.

Should there be a permanent shortage of fuel oil or an excessive increase in its cost, it would be possible to replace the Diesel units with alternating-current motors and drive the plant with current from shore or to place on board a rotary converter to permit the use of alternating-current shore power.

THE MAIN ELECTRIC GENERATORS

There are four direct-current generators of the constant-voltage, compound-wound, commutating-pole type, direct connected to the main Diesel engines. The compound winding on these generators is only sufficient to compensate for the variations in speed of the Diesel engines as found by experience.

The windings of these generators received a special impregnation and baking and all metal fittings are of the marine type to protect from moisture and corrosion.

The generators connected to and driven by the 800-b.hp. after engines are each of 540 kw. capacity at 200 r.p.m. The generators connected to and driven by the 900-b.hp. forward engines are each of 610 kw. capacity at 150 r.p.m. All these generators deliver power at 500 volts to the main bus which acts as a power line from which power for all units is primarily taken.

This allows for great flexibility, simplicity, and efficiency of control and operation. The main engines may be operated either singly or in any combination, also the speed of the dredging-pump motor and cutter motor can be varied to suit the power available or conditions of operation.

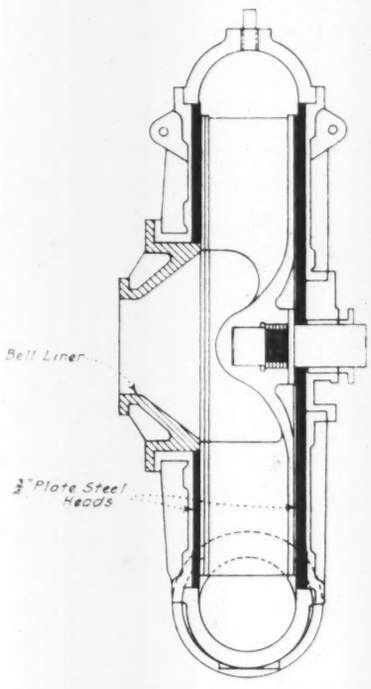

FIG. 10 PUMP ASSEMBLY, SHOWING LINERS

The Switchboard. On the port side of the dredge, on the main deck in the engine room, is located a switch board of 17 panels. The equipment of these panels is as follows:

PANEL NO. — EQUIPMENT AND USE

1 Water, oil and air pressure gages, electric pyrometer, and a multiple-contact pyrometer switch of 32 contacts.

2 Graphic meters for the forward-swing motors and the cutter motor.

4 Circuit breaker, ammeter, rheostat, handwheel, voltmeter switch, field-discharge switch, two heavy knife switches, watt-hour meter with knife switch, and magneto-operated speed indicator for control of the 610-kw. generators.

5, 6, 7 Duplicates of panel No. 4; used for control of second 610-kw. generator and of the two 540-kw. generators.

8 For dredging-pump motor; installed thereon are the electrically operated circuit breaker and field switches.

9 For control of feeder to 2700-hp. dredging-pump motor; has four sets of heavy knife switches, a graphic wattmeter, and a watt-hour meter as well as an 8-day clock.

10 Controls of alancer set; consist of a special two-pole automatic, circuit breaker, two ammeters with scale for each main lead, a rheostat handwheel, and a 2-pole knife switch.

11 Feeder panel for balancer set; contains two 2-pole manually operated circuit breakers, two ammeters, one voltmeter, one 3-wire voltmeter switch, two 2-pole knife switches, two push-button "Start" and "Stop" for balancer set, and a 3-wire watt-hour meter with two shunts.

12 For 250-volt feeders; contains voltage regulator, voltage balancer relay, four 2-pole knife switches, one voltmeter (ground detector) and one 6-position ground detector switch.

13 Has sixteen 2-pole switches for 250-volt feeder with fuses.

14, 15 Duplicates, the first for control of 2-wire 75-kw. auxiliary generators, the second for control of the 60-kw. 3-wire generator of the balancer set. Mounted on each panel is a 2-pole manually operated circuit breaker, two ammeters, one voltmeter, one three-wire voltmeter switch, one rheostat handwheel, one 3-pole knife switch, and a 3-wire watt-hour meter with shunts.

16 Contains a 3-pole manually operated circuit breaker with shunt trip, twelve 2-pole knife switches with fuses and a double-pole knife switch with fuses.

17 Contains gages, graphics and push buttons for control of the cutter motor and main pump motor.

All 500-volt knife switches of 800-ampere capacity and below are mounted on back of board. All knife switches above 800-ampere capacity in 500-volt circuits are provided with covers.

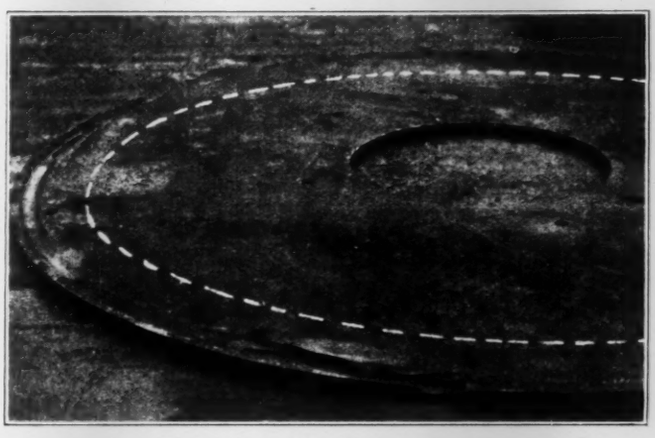

FIG. 11 HEAD LINER OF $\frac{3}{4}$-IN. STEEL FROM SLOW-SPEED PUMP SHOWING EXCESSIVE WEAR AT EDGE BUT WITH SURFACE INSIDE DOTTED LINE REMAINING GOOD

(Liner was later redesigned with center in one piece and outer rim in sections easily replaced.)

The electric system in general is as follows:

The main generators deliver power to the main bus of 500 volts, about 85 per cent of the power being taken from this bus for operation of the main pump motor. The remainder of the electric equipment operates at a lower voltage, and to obtain this conversion a balancer set is introduced which consists of two 250-volt machines coupled together and operated in series from the main bus. A lead from the common connections of these two machines, in conjunction with the two leads from the main bus, forms a 250/500-volt 3-wire system. By distributing the 250-volt motors on each side of the neutral lead it is possible to obtain a good natural balance, so that very little power will actually pass through the balancer set and there will be practically no power loss.

The balancer-set units are made large enough to act as motors to drive three generators. One generator furnishes power for operating the cutter motor by the variable-voltage or Ward Leonard system. The second generator provides power for operating the forward swing motor by the variable-voltage or Ward Leonard system. The third, a 125/250-volt d.c. 3-wire generator, is for lights, excitation of variable-voltage generators, small motors, and auxiliaries. There is a 75-kw. 125/250-volt 3-wire auxiliary generator direct connected to an auxiliary Diesel engine which supplies power to the above-mentioned 3-wire system when the main generators are shut down.

THE DREDGING PUMP AND MOTOR

The dredging pump for the *Clackamas* (Fig. 9) is a high-speed square-volute lined centrifugal-type pump developed by the Port of Portland, having 30-in. suction and discharge openings. The casing is rectangular in section and 8 ft. $10\frac{1}{2}$ in. in diameter inside

of the liners which are of mild steel 3/4 in. thick (Fig. 10). The casing is 2 ft. 5 in. wide inside the liners. It is made of cast steel to provide extra strength and reduce weight. This reduces the possibilities of breakage from boulders or water ram and also facilitates patching by electric welding. Being of rectangular section concentric with the impeller simplifies the machining of the head liners and the periphery liners. The liners are made in sections to minimize the expense of replacing any section worn out (Fig. 11).

Certain liner sections deteriorate from wear sooner than their neighbors, but by replacing them the condition of the pump is maintained, as well as its high efficiency. Provision is also made for the substitution of rubber or cast-iron liner sections. There are certain dredging conditions where it appears advisable to use the latter types of pump liners.

The impeller, which is screwed on to the pump shaft so that it

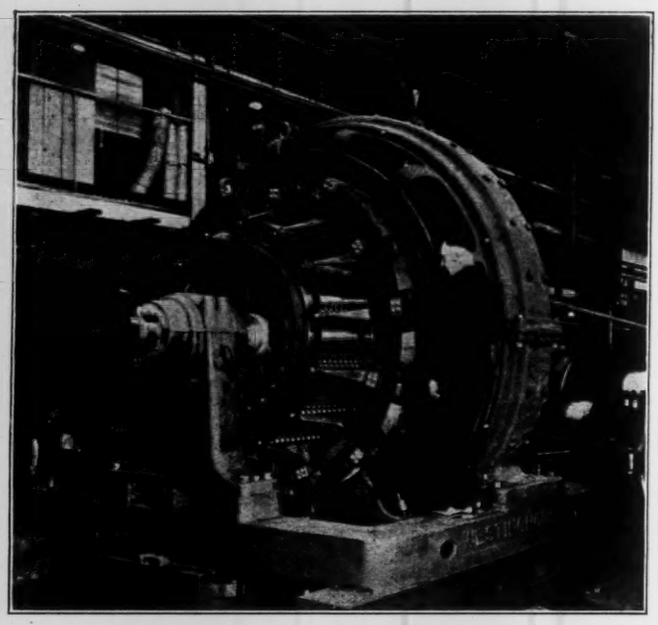

FIG. 12 2700-HP. WESTINGHOUSE D.C. MOTOR FOR DREDGE PUMP

may be more readily removed to replace back head liners, is of the four-spiral-vane enclosed type, 70 in. in diameter, and driven at speeds ranging from 250 r.p.m. to 360 r.p.m. by a 2700-hp. electric motor. On account of this wide range of speed adjustment it is believed by the author that all dredging conditions of long or short discharge pipe, light or heavy material being dredged, or amount of terminal lift, etc., can be met without changing the size of the impeller.

The impeller shaft, which is of nickel steel and 11 in. in diameter, runs at one end in a special self-aligning bearing bolted to the pump casing; the other end is connected by a solid coupling to the thrust shaft.

The pump motor is a 2700-hp. 250- to 360-r.p.m., 500-volt, adjustable-speed, compound-wound d.c. machine direct-connected through a flexible coupling and marine horseshoe-type thrust bearing to the dredging pump. It is the largest of its kind ever to be built for dredging purposes. The compounding is adjustable to give a no-load speed of 450 r.p.m. and a full-load speed of 360 r.p.m. and the motor has a rising speed characteristic, giving additional velocity and maintaining torque to clear the discharge-pipe line in case of chokings.

The pump motor is controlled by motor-driven rheostatic controllers operated by push buttons. Pushing the starter button located on the engine-room switchboard will start the motor and it will come up to speed automatically; the last point on the controller will close the circuit breaker, cutting out the starter, and leave the motor operating at a speed corresponding to the position of the motor-operated field rheostat. Speed adjustment is then obtained by pressing the "fast" or "slow" buttons either on the panel in the engine room, or a similar button in the pilot house. When the speed has reached the desired point (as shown by the indicator) the button is released and the speed stays at that point as long as power is available at the main bus. To stop the motor the "stop" button is pressed either in the pilot house or the engine room.

For emergency operation an "inching" push button is provided in the pump room. This causes the motor to turn very slowly for making repairs or cleaning until stopped by releasing the push button. A reversing field switch on the engine-room switchboard will allow the pump motor to operate in the reverse direction up to full speed if desired. The small motors for the control rheostats obtain their power from the 125/250-volt generator forming a part of the balancer set.

THE CUTTER MOTOR AND DRIVE

The cutter is driven by an electric motor through a chain of gearing. Two of the gears in this train are made interchangeable so that the maximum speed, 12 r.p.m. of cutter, at maximum motor speed can be practically doubled to 25 r.p.m.

The cutter motor (located below the main deck in the forward port wing) is a 250 hp., 600-r.p.m., 275-volt, shunt-wound separately excited machine connected to the cutter drive by a Thomas flexible coupling. It receives its power from the 200-kw. generator of the balancer set and is controlled by a reversing drum controller, located in the pilot house, providing 14 speed points in either direction by controlling the shunt-field excitation of the generator, and thus producing the variable voltage of the Ward Leonard system. By means of this arrangement the speed of the cutter motors may be adjusted from the pilot house, giving cutter speeds from 12 r.p.m. down to meet any condition of dredging, or from 25 r.p.m. down, depending on the setting of the interchangeable gears.

THE DREDGING LADDER

The dredging ladder is the standard Port of Portland type, 75 ft. long, 10 ft. wide and 8 ft. 6 in. deep, of open rectangular-frame construction.

Four heavy structural-steel angles extend the full length of the ladder, one in each corner, separated into panels by diaphragm bracing spaced approximately 10 ft. from center to center between the ends; each panel (top, bottom, and sides) is cross-braced by heavy channels and plate gussets, forming a light and extremely rigid structure.

The cutter shaft is located inside of the ladder and carried in bearings near the top. The suction pipe is also inside the ladder, carried in saddles near the bottom. This construction allows the cutter to work in very shallow dredging without the ladder's dragging on the bottom during the swing. The base of the ladder is provided with hollow cast-steel trunnions or hinges for attaching to the hull. The suction pipe from the ladder passes through the starboard trunnions and packing gland into the hull and to the dredging pump.

The cutter shaft is driven by a heavy train of gearing and a shaft passing through the port trunnion from the cutter-motor gear train. This train of gearing is of cast steel with milled teeth. The cutter shaft is of steel and 8 1/2 in. in diameter, increased to 10 in. at the cutter-head bearing and tapered square where fitting into the hub of the cutter.

The cutters (see Figs. 13 and 14) used are about 5 ft. long and 6 ft. or more in diameter.

The varying conditions of the material dredged demand that different designs of cutters be used and driven at varying speeds and powers. Hard-pan requires slow speed and high power, and fine sand or silt, high speed and rapid feed, to supply material to a high-powered dredge. Various types of cutters have been used, each satisfactory for certain conditions. These cutters are interchangeable on the different dredges.

The suction pipe from the ladder terminates at the dredge pump, where an easily removable section is installed having a manhole in its upper surface for inspection purposes and for removing material that has lodged at the entrance to the pump. From the pump the discharge line passes aft on the starboard side below the main deck, rising at the stern through the after deck and connecting into the gooseneck bend. The outboard end of the gooseneck connects by means of a packing gland and swivel elbow to the pontoon pipe leading ashore.

AUXILIARY MACHINERY

The Balancer Set. To supply power to the various auxiliary motors and electric equipment a balancer set was installed on the port side forward of switchboard made up of various units direct connected together consisting of the following:

Two 200-kw., 1200-r.p.m., 250-volt, d.c. units operated in series from the main 500-volt bus for furnishing neutral for 250/500-volt 3-wire system and power for driving three generators as below.

One 200-kw., 1200-r.p.m., 275-volt d.c. generators for furnishing power to operate cutter motor by the variable-voltage or Ward Leonard system.

One 60-kw., 1200-r.p.m., 250-volt, d.c. generator for furnishing power to operate forward swing motor by the variable-voltage or Ward Leonard system.

One 60-kw., 1200 r.p.m., 125/250-volt, d.c. 3-wire generator for furnishing power for light, excitation of variable-voltage-control generators and motors, and small auxiliaries.

This balancer set is so constructed that all armatures for the three 200-kw. units are interchangeable as well as those for the two 60-kw. units, thus reducing the number of spare parts and facilitating repair work.

Winches and Motor Drives. On the main deck of the dredge near the forward wall of the house is installed a three-drum winch equipped with clutches, brakes, and gypsy heads.

Two of these drums are driven through clutches and gears by a layshaft extending across the lower steel house and through the side walls with a gypsy head on each end outside the house. This layshaft is carried in bearings mounted on structural-steel stands of box construction and is driven through a train of gearing by a 75-hp., 600-r.p.m., 230-volt, shunt-wound separately excited motor of heavy open construction which takes its power from the 60-kw. generator of the balancer set and is controlled by variation of the field of this 60-kw. generator by the Ward Leonard system, the same as the control of the cutter motor. This system gives a great range

FIG. 13 CUTTER OF DREDGE CAKED OVER WITH BLUE CLAY, BLOCKING SUCTION

of speed and power for swinging the cutter into the bank to be excavated.

In addition there is a master controller for the operation of the brake and clutch of each drum through the agency of compressed air. Except for the two swinging-wire drums, where adjustable foot brakes are provided as here, adjustable braking power is essential.

The wire cables from these drums are led through specially mounted swinging blocks on the dredging ladder just aft of the cutter and from there to heavy anchors set with sufficient spread and forward lead to give the desired radius of action.

Mounted on the same frame and considered a part of the forward winch is the ladder hoist mechanism which consists of a single drum positively connected through a train of gearing to a 45-hp., 515-r.p.m., 230-volt, series-wound motor with magnetic brake.

The controller is similar to that for the crane hoists: the speed of the motor while lowering is regulated by regenerative braking; should there not be sufficient strain in the hoist cable to revolve the drum when lowering, then the motor is reversed and will assist. The speed of the motor is at all times under control of the operator whether lowering or hoisting. There is also an independent brake on this system operated manually to be used in cases of emergency.

The cable from this drum leads to the multiple-sheave hoisting tackle, the upper member of which is built into the outer end of the A-frame and the lower member connected by a chain bridle to the outer end of the digging ladder.

On the main deck just forward of the after wall of the house is installed a four-drum winch equipped with clutches, brakes, and

FIG. 14 VARIOUS TYPES OF CUTTERS USED IN PORT OF PORTLAND DREDGES (Those with open framing are used for clay. Where much trash and sticks is encountered, the close-set knife type is used.)

gypsy heads and driven by a 45-hp., 515-r.p.m., 230-volt d.c. series-wound motor with magnetic brake through a gear train and layshaft.

Two of the drums are for the swing cables which pass through the after wall of the house near the deck and through quarter-blocks to the anchors set in the bed of the river. The other two drums are located in line with the spud masts. Each spud hoist cable leads from its drum through the after wall of the house in a direct line to a fair lead sheave framed into the upper truss member just aft of the spud mast and from there over the top of the spud-mast sheave to a floating sheave toggled to a steel rail let into the back of the spud. Each drum is independently controlled by a gravity-applied, air-released brake and an air-applied clutch, all controlled by a master switch in the pilot house. The motor of this winch is controlled in the same way as the ladder hoist motor hereinbefore described.

Auxiliary Diesel Engine. On the main deck aft of the 800-hp. engines is installed an auxiliary 110-hp., 4-cylinder, 4-cycle, Atlas-Imperial, solid-injection Diesel engine direct connected to a 75-kw., 325-r.p.m., 125/250-volt, 3-wire compound-wound, d.c. generator. Installed on the same foundation is a small gasoline-driven air compressor for furnishing starting air for the auxiliary engine in case the air tanks become exhausted.

The auxiliary generator delivers current to the bus on main switchboard for operating the pumps, machine tools, lights, galley equipment and other auxiliary machinery when the main engines are not operating, as on Sundays, holidays, or during repair periods.

Auxiliary Compressors. Installed on the main deck just forward of the balancer set, on the port side are two Rix motor-driven air compressors. One of these is a two-stage compressor driven by a 25-hp. electric motor and delivering air at 50 lb. pressure, the second is a booster compressor driven by a 10-hp. electric motor, receiving air at 350 lb. from the two-stage compressor and delivering it at 1000 lb. pressure where needed. These compressors have interconnecting air piping to all air tanks and air bottles to fill them in case they become exhausted and the main engines all be idle.

Auxiliary Pumps. There are a number of motor-driven auxiliary pumps installed below the main deck, most of them against the longitudinal bulkhead on the port side. In many cases there are duplicate pumps used for the same service to allow repairs to be made without interfering with the operation of the dredge. In

some of the more important systems the duplicate pump is placed in a different compartment than its mate so that the system will not be deranged in case of a flooding of one of the compartments. These pumps are as follows:

Fire pumps, 2, each 500 g.p.m. against 100 lb. pressure, 50 hp. motors	Morris Machine Works double-suction pumps direct connected to 230-volt adjustable-speed d.c. motors controlled by starting and speed-regulating rheostats and running at 1150–1700 r.p.m.
Engine-circulating-system pumps, 2, each 900 g.p.m. at 45 ft. head, 15-hp. motors	
Bilge pumps, 2, each 60 g.p.m. at 100 ft. head, 5 hp. motors	
Potable-water pumps, 2, each 60 g.p.m. at 100 ft. head, 5 hp. motors	
Hot-water circulating pump for heating system, 1, 60 g.p.m. at 100 ft. head, 5-hp. motor	
Fuel-oil pumps, 2, 125 g.p.m. at 100 lb. pressure, 10 hp. motors	Northern rotary pumps driven by 230-volt, 850–1200-r.p.m. adjustable-speed d.c. motors.
Diesel-oil pump, 1, 125 g.p.m. at 100 lb. pressure, 10-hp. motor	
Piston-oil cooling system pumps, 3, each 100 g.p.m.	Kinney rotary, gear driven by electric motor.
Lubricating-oil-system pumps, 3, each 2 g.p.m., driven by 1/2-hp. motors	Goulds double rotary.
Fuel-oil centrifuge	Sharples No. 6, driven by 3-hp. motors.
Lubricating-oil centrifuge	

Other Auxiliary Equipment. The *Clackamas* also is equipped with a Frick self-contained refrigerating machine of 2 tons refrigeration capacity, belt-driven by a 3-hp. d.c. motor, which furnishes refrigeration for the 7 1/2 x 10-ft. cold-storage room, the ice-making brine tank (for six 50-lb. cakes), and the scuttle butt.

The machine shop is located on the main deck and consists of the following tools, all motor-driven: American 24-in. by 16-ft. heavy-duty back-geared engine lathe; Fosdick 42-in. heavy-duty radial drill; Gould & Eberhardt 24-in. back-geared shaper; Canedy Otto 21-in. back-geared drill press; Economy ball-bearing grinder; Landis 2-in. bolt cutter with pipe-threading dies.

There are three Cyclops Iron Works hand-operated traveling cranes installed; one of 10 tons over the 800-hp. main engines just under the cabin deck beams operates between the bulkhead back of the auxiliary Diesel engine and the aft cylinder of the 900-hp. main engine. This crane serves the 800-hp. engines and generators and the generators of the 900-hp. engines as well as the auxiliary Diesel engine and generator. In the 900-hp. engine casing just under the upper deck beams is installed a 5-ton crane which serves the 900-hp. engine and operates the length of the engine. The third crane, of 5 tons capacity, operates from the forward part of the 900-hp. engine to the forward bulkhead of the lower house and serves the dredging pump and motor, the heavy machine tools and the forward winch. These cranes in conjunction travel the length of the machinery space and it is possible to transfer a load from one to the other.

The Mechanical Features of Salmon Canning

Early Methods Employed in Can Making and Canning—Modern Methods in Which Rapid-Working Automatic Machines Have Replaced the Former Hand Methods—Present Extent of the Industry

By M. L. DODGE,[1] SEATTLE, WASH.

OUR PRESENT-DAY salmon canneries are a mechanical development extending over quite a period of time, the first cannery on the Pacific Coast having been established in 1864, on the Sacramento River, in California. Salmon canning presents many features of interest to the mechanical engineer.

Early Methods

It is interesting to compare early methods with those of the present day. The cans were at first all made by hand with very primitive tools. A square shear operated by a foot treadle cut the sheets of tin into a size for the can "body." A line was scribed along one end with a tool on the order of a thumb gage. A hand roll rolled the body into a cylinder and it was lapped to the line already mentioned. Then it was tacked with solder at one or two points to hold it in place, then held against a block bolted to a bench with a hand tool, and the remainder of the side seam soldered. At a little later date a form of the exact size of the inside of the can was made and a clamp, operated by a foot lever, held the can body in place while the side seam was soldered.

By this method an expert can maker could solder from 3500 to 4000 can bodies in ten hours. This was soldering the side seam only. It required a second man to cut the blanks and another to roll them into the cylindrical shape, or three persons to make the 4000 can bodies in ten hours. Today a machine with two operators can make 150,000 cans every ten hours.

The ends were made by cutting circular disks from sheets of tin with a rotary shear. The edges of these disks were flanged down in a crude cast-iron die which was operated by a hand screw press.

In assembling the can, the bottom was slipped over the body and the end of the can rolled about in a pan of powdered rosin. A piece of solder was placed inside and a hot soldering copper curved to the shape of a can was applied outside, and by revolving the can the solder was spread around in the joint. After filling with fish the tops were inserted in the end of the body and soldered by hand around the edge.

The processing, at that time very much of a secret, was simply a case of cooking in water tanks instead of using a retort as at present. The cans, which had a vent hole in the top, were first placed in trays and immersed in boiling fresh water to within perhaps an inch of the top. After they had been cooked for an hour in this manner, they were removed from the water and sealed by a drop of solder put on each vent hole. They were then put into a tank of boiling salt water where a higher temperature was obtained than would be possible with fresh water. After cooking for another hour they were washed by hand with soap and water and a rag, and then painted with red lead and linseed oil.

Such were the primitive methods of can making and canning of the early days.

The First Automatic Can-Body Maker

About 1883 the first automatic body maker was brought into use on the Pacific Coast. This machine turned out lock-seamed can bodies at the rate of twenty a minute. This was improved until a speed of sixty-five per minute was attained. The Seattle-Astoria Iron Works built its first body machine, still in use, in 1907, at Astoria, Oregon. By this time presses and dies, more on the present-day order, were in use. The tin was fed by hand, however, but the die did its own blanking. An operator on a press could feed on an average about sixty ends a minute.

Modern Methods of Can Making

The cans of this period still had soldered ends. However, a steady improvement in mechanical devices for can making has been in progress and at present there is machinery in Seattle that will make cans at the rate of 260, or even faster, per minute, automatically feeding and forming the body from a blank, and lock-seaming and soldering it. Cans manufactured thus are called "sanitary" cans, probably because in the machine-soldered can all the solder is on the outside of the body and the ends are double lock-seamed, with no solder whatever.

The body maker is perhaps the most complicated and particular machine used in the making of cans and requires the most expert mechanical attention. The body itself, before either top or bottom is put on, goes through no less than thirteen distinct operations. These operations are as follows:

The commercial size of tin plate is first fed to the "trimmer,"

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which is a series of circular cutters spaced to cut the large sheet into strips of exact width to make the circumference of the can plus the hooks for the lock seam. Next in order is the "slitter," which cuts these strips into body blanks of a sufficient width for the height of the can. The body maker feeds these blanks automatically from a stack to the first station where the ends are notched. The blank is then moved forward to the first folding operation, and then to the second folding operation; these form what are known as the "hooks" for the lock seam. Next a small roller prefluxes the edge of one hook, to insure the solder's entering the seam and sweating clear through the joint. Then comes the forming of the body around a "horn." This is done by wings swinging down from above and folding the tin around the horn. This horn is a very important part of the machine, for it controls the exact diameter of the finished can. It is a collapsible arrangement with means for expanding to pull the hooks together after the forming wings have overlapped them. The seam is next "bumped," or flattened out, by a ram from below. The can has now taken shape and must be soldered. An endless chain with attachment hooks picks the cans off the horn and propels them along a solder horn, first over a fluxing roller and then over a soldering roller, the latter being partly immersed in molten solder. They are next wiped by a wheel composed of muslin disks and similar to a buffing wheel, which takes off the surplus solder. As the cans are still very hot and the solder not set, it is necessary to cool them with an air blast.

A conveyor carries the cans to the "flanger," where both ends are flanged preparatory to the application of the bottom. Another conveyor takes them from the flanger to the "double seamer," or closing machine. This machine also has a very important function to perform: it places the bottom on the body and rolls a lock seam. This requires two operations, the first one a sort of tucking the edge of the bottom up under the flange of the body, and the second a flattening-out process to lay the laps of tin tightly together to prevent leaks.

A pressure of about 200 lb. is required to roll the second operation tight. The rollers are diametrically opposed and are operated by a toggle. A chuck fits the depression in the can end, forming a solid support for the seam during the rolling operation. After the cans have been tested for leaks, they are ready for the canner.

The can end which has just been put on the can in the double seamer requires quite an outlay for machinery for its manufacture. To avoid waste of tin plate, a scroll shear is employed to cut strips for the automatic press. To cut straight strips and then punch round disks out of them obviously creates a waste in the form of a triangular-shaped piece between each two holes and the edge of the strip. The scroll shear takes advantage of a staggered layout of holes, thus reducing the waste to a minimum.

These strips are stacked in the hopper of the press and are fed automatically to the die. A modern press will make ends for a tall 1-lb. salmon can at the rate of 250 per minute. A strip of tin is taken from the hopper and placed on the feed bar, which moves it along intermittently under the die. When all the ends are cut from this strip, the scrap that is left is thrown out at one side, while another strip is picked out of the hopper and placed on the feed bar. One strip follows another closely; there are no idle strokes of the press.

The ends, after being dropped out of the die, slide down a chute into a "curler," which is simply a revolving disk or ring with a groove in its edge and a stationary segment outside of this, with a corresponding groove on its inside edge, the space between the two being sufficient to accommodate the diameter of the end. The end sliding down the chute from the press is guided in between the revolving disk on one side and the end of the segment on the other side. The revolving action of the disk rolls the end around the segment and throws it out at the discharge end. This turns the edge under slightly, making it possible to stack the ends without their sticking together.

From the curler the ends must go through the compound-applying machine, which places a thin coating of rubber compound inside the edge. This compound forms a gasket in the seam when the end is rolled on to the body. After applying the compound, which is in liquid form, the ends pass through a drying process before they can be handled or boxed for shipping.

MODERN CANNING METHODS

Improvements in can making have been accompanied by corresponding improvement in handling and canning methods. Power boats with winches handle fish traps and dump the fish by the ton into scows or into fish tanks in the trap tender for transportation to the cannery where they are handled by a modern elevator. The modern fish-cleaning machine trims, washes, and scrubs the fish in a more thorough manner than was usually done by hand, and the man with the butcher knife has been replaced by the "fish cutter," an endless chain carrying sectional buckets or fingers past revolving circular knives that cut the fish to proper length for a can.

Hand filling is practically a thing of the past. The first machine filler was built by Mathias Jensen, of Astoria, in 1875, and operated at a speed of about twenty cans per minute. With refinements of design the present Jensen filler, while employing the principles of the original, is a very quiet, smooth-running machine, capable of filling from 80 to 100 cans per minute, and putting a measured amount of salt in each can besides.

As an example of refinement in design may be cited the cam that operates the plunger on the can filler. For several years the usual method of making this cam was to rough-mill it to approximate shape, place it on a machine, and chip and file the surface to a fair contact with the roller. The roller pin did not point to the center of the shaft, and the cam had a long travel and mostly on one side of the center line. By redesign of the lever carrying the roller and its bearing bracket, equalizing the travel on each side of the center, and making the axis of pin radial with the cam, it is possible now to mill the cam to such a degree of accuracy that hand fitting, which formerly consumed from two to four days, is no longer necessary.

From the filler the cans of fish are carried on a chain or belt over a "mending" table, where small pieces of fish may be placed in cans to fill up any space that may be left by the filler. They then go to the "clincher" where the cover is put on and the edge crimped over the flange of the can body enough to keep it in place and yet allow the air to escape as the can is heated in the exhaust box.

The clincher has developed in the past few years from an intermittent-motion squeezing arrangement to a continuous rotary rolling process of almost unlimited speed, and its efficiency is shown by the fact that this machine has been in practical use now for five years with no changes in design.

From the clincher the can passes to the "exhaust box," whose function is to heat the contents of the can to about 200 deg. fahr. and drive out all the air possible prior to sealing the top on. It consists of either a series of disks with gear teeth on the edges and a sort of figure-eight guide, or a chain arrangement to take the cans back and forth through the box, keeping them in a bath of steam for from 12 to 15 minutes.

Leaving the exhaust box, the next step is to double-seam the cover on. This is called the closing operation. The closing machine may well be called the most important machine in the cannery, for upon its work depends the whole success of the pack. The manufacturer of the cans, if the canneryman buys his cans, will guarantee to make good all claims for spoilage due to leaky cans for any amount greater than 5 cans in every 1000, provided the leak occurs in the side seam or the end put on when the can is manufactured. If there is anything wrong, however, with the end that the canner puts on, it is the canner's loss.

The present double seamer has not undergone so much redesign as has most of the other canning equipment, due to the fact that the original designer of the machine was a finished mechanical engineer. Small refinements have been added in the past few years to take care of a demand for increased speed. Some bearing sizes have been increased, and safety devices added.

The remainder of the canning operations are not of so much importance from a mechanical standpoint, as they are simply cooking, washing, inspecting, labeling and shipping processes.

To give an idea of the size of the industry at present, it may be said that there were 188 canneries in the states of Washington and Oregon and the Territory of Alaska in operation for the season of 1924. Their total output was approximately six and a quarter million cases, which, at 48 one-pound cans to the case, represents a sales value of $44,000,000. Of this number over five million cases were put up in Alaska.

Standardization of Machine Tools

The Status of Standardization of Machine Tools in the United States and the Various Agencies Through Which the Work is Being Performed

By S. EINSTEIN,[1] CINCINNATI, OHIO

IN PRACTICALLY every technical journal nowadays, articles frequently appear describing one phase or another of standardization, and quite often they endeavor to show that standardization in a broader sense is the problem of today and is indispensable to the industrial life of the country.

On the other hand, we hear occasionally voices raised against standardization as destroying individuality. Nevertheless facts show that it is a check to individuality only if the latter is superficial and useless. Standardization encourages individuality where that feature counts most.

Secretary of Commerce Hoover, in discussing the problem of elimination of waste in industry has said:

> It is certain that there are a great many articles of every-day use in the standardization of which the manufacture would indeed be glad to coöperate, which would mean a saving in national effort interpreted not in millions but in billions of dollars. This does not mean, however, that we stamp the individuality out of manufacture or invention or decoration; it means basic sizes for common and every-day things.

Webster defines a standard as "that which is established by authority, custom, or general consent as a model or example." Probably the most important standard of an international nature is our alphabet, which is used, with few exceptions, in all modern languages. The standardization of the meaning of words, of spelling, and of pronunciation is laid down in the dictionaries. The standardization of coinage, weights, and measures is essential in the life of every nation.

A Few Historical Data

Standardization of certain mechanical elements began a good many years ago in this country, the most typical example being probably the attempt to standardize screw threads.

In 1864 a committee of The Franklin Institute recommended the adoption of a system devised by William Sellers, now known as the United States Standard. In 1884 Charles A. Bauer, of Warder, Bushnell & Glessner, Springfield, Ohio, adopted standard sizes of screw threads for bolts and taps, based upon the United States Standard screw thread. In 1895 the Hartford and Worcester machine-tool builders issued standards for setscrews and capscrews, also based upon the United States Standard screw thread. In 1906 the Association of Licensed Automobile Manufacturers adopted standards for automobile screws and nuts.

In 1907 The American Society of Mechanical Engineers accepted the report of its committee on standard proportions for machine screws. This committee was appointed in 1902, and had devoted five years to the task. As far as the screw-thread shapes are concerned, the A.S.M.E. standard differs only in very minor details from the Sellers or United States Standard, but the report of the Society's Committee gives standards also for taps, special screws, special taps, and screw heads of various types, together with tolerances.

In 1912 the Society of Automobile Engineers was organized and later adopted a fine-screw-thread standard, as well as many other dimensional standards for automobile materials and parts.

In July, 1918, the National Screw Thread Commission was appointed by Act of Congress, and after three years of painstaking work it published its first Progress Report in January, 1921. This report was broadly distributed and was carefully studied by the Sectional Committee on the Standardization and Unification of Screw Threads organized under the procedure of the American Engineering Standards Committee. The Sectional Committee conferred with the N.S.T.C. and made a number of important recommendations, all of which were accepted by the latter.

The report of the Sectional Committee was approved by the S.A.E. and The A.S.M.E., its joint sponsors, in the spring of 1924, after which it was approved by the A.E.S.C. and published in pamphlet form in May, 1924. The final report of the N.S.T.C. was then issued in February, 1925.

This brief outline of the course of events necessary to unify the screw-thread systems of this country indicates plainly the length of time which is necessary to carry on such standardization activity, particularly when the product under consideration is as important a mechanical element as screw threads.

Stages in Standardization

Standardization can be considered as having passed through four stages: namely, (1) standardization within the factory; (2) standardization within certain industries; (3) national standardization; and (4) international standardization.

Every factory, large or small, has of course certain individual standards. The sizes of drawings and tracings, the information on these drawings, the method of dimensioning, and certain shapes and features of designs are generally standardized. It has a standard of materials, a standard of stock parts such as special screws, bolts, pins, levers, etc. It occasionally standardizes a unit so that it will be interchangeable and can be used on various sizes and styles of machines, such as drive and feed-change mechanisms, friction clutches, tool posts, tool holders, vises, chucks, aprons, tailstocks, etc. It generally standardizes the manufacture of various machines of the same or different design. It builds these machines in certain fixed quantities at one time; it has a standard system of issuing orders and has standardized the manufacturing of these parts. It has standard equipment and standardized tools for the manufacture of these machines. In short, each and every department has certain functions to perform and they all follow a certain standard in performing them.

This standardization within the factory can be, and in larger organizations is, of the greatest importance. The standards developed there are and must be the foundation of any new standard, inasmuch as they give the men entrusted with standardization a basis upon which to develop the new standard. A very interesting paper on this subject is entitled Intra-Company Standardization and Its Relation to General Standardization, by E. A. Johnston and O. B. Zimmerman, Engineers of the International Harvester Company.[1]

The next stage is the standardization in specific industries through trade associations and technical societies, and deals particularly with the standardization of certain functional or structural elements of the product of that industry. It has for its object standardization of sizes, styles, and dimensions to permit the same standardized parts to be included in various makes of machines. As a very typical example of this stage may be mentioned the various standards which were adopted by the automobile industry: namely, the standardization of tires, starting units, spark plugs, carburetors, etc. The same standardization method is followed by the electrical industry. Electric lamps are generally interchangeable in the same socket. Standardization within the industry deals also with standardized specifications and standardization of certain fundamental dimensions; for example, in the milling-machine industry the ranges of the various sizes of knee-and-column-type milling machines are standardized. It deals also with the standardization of certain safety codes, etc.

Of still larger scope is standardization on a national scale. Practically all of the civilized countries today have bodies which take care of national standardization on a larger or smaller scale—Australia, Austria, Belgium, Canada, Czechoslovakia, Finland, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Norway, Poland, Russia, Sweden, Switzerland and the United States, nineteen in all.

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[1] Chief Engineer, Cincinnati Milling Machine Co. Mem. A.S.M.E.

[1] *Agricultural Engineering*, vol. 4, no. 12, Dec., 1923, pp. 187–191.

THE AMERICAN ENGINEERING STANDARDS COMMITTEE

In the United States the function of national standardization is accomplished by the American Engineering Standards Committee, which serves as a national clearing house for engineering and industrial standardization, acts as the official channel of coöperation in international standardization, and provides an information service on engineering and industrial standardization matters. However, it may be said here that the ultimate responsibility for and control of the work rests with the member bodies of the organizations whose representatives constitute the American Engineering Standards Committee. It is the agency through which industrial standardization in this country is passing from the second to the third stage, namely, from standardization by associations, societies, and governmental agencies to standardization on a national scale. At the time of the organization of the American Engineering Standards Committee, there were hundreds of organizations publishing standards, most of which were formulated without systematic methods of coöperation or exchange of information between the organizations concerned.

The Committee had its beginning in January, 1917, at a meeting of a special committee appointed jointly by the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Society for Testing Materials, for the formulation of some method of cooperation to prevent duplication in standardization work and the promulgation of conflicting standards. As a result of this and subsequent meetings the A.E.S.C. was organized, made up of representatives of the five societies mentioned. The first meeting was held in October, 1918. Later, upon invitation, the War Department, Navy Department, and Department of Commerce of the U. S. Government designated representatives to serve on this Committee. It would require too much space to discuss here the method of work of the various Sectional Committees appointed under the A.E.S.C. procedure and what they have so far done. The Year Book of the American Engineering Standards Committee gives a true picture of its accomplishments. The different steps in the development of standardization projects submitted to the A.E.S.C. for approval are shown in Fig. 1.

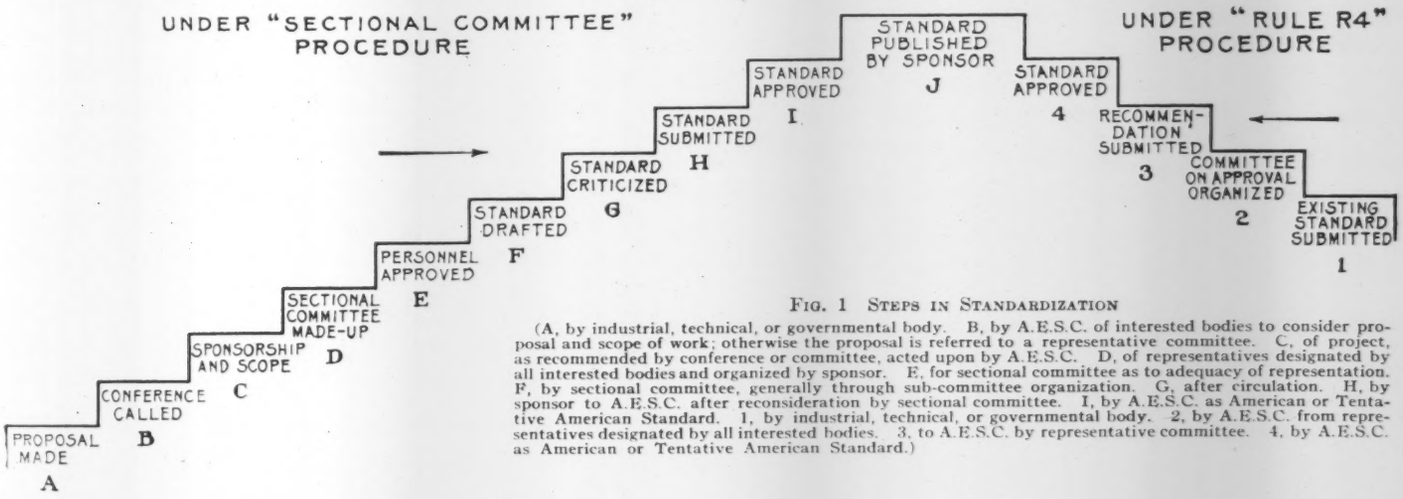

FIG. 1 STEPS IN STANDARDIZATION

(A, by industrial, technical, or governmental body. B, by A.E.S.C. of interested bodies to consider proposal and scope of work; otherwise the proposal is referred to a representative committee. C, of project, as recommended by conference or committee, acted upon by A.E.S.C. D, of representatives designated by all interested bodies and organized by sponsor. E, for sectional committee as to adequacy of representation. F, by sectional committee, generally through sub-committee organization. G, after circulation. H, by sponsor to A.E.S.C. after reconsideration by sectional committee. I, by A.E.S.C. as American or Tentative American Standard. 1, by industrial, technical, or governmental body. 2, by A.E.S.C. from representatives designated by all interested bodies. 3, to A.E.S.C. by representative committee. 4, by A.E.S.C. as American or Tentative American Standard.)

In all 68 standards have been approved by the American Engineering Standards Committee, and 91 others are under way. Of the total 159 projects submitted, 32 have to do with civil engineering and the building trades; 26 with mechanical engineering; 17 with electrical engineering; 4 with automotive subjects; 9 with transportation; 1 with shipbuilding; 9 with ferrous metals; 14 with non-ferrous metals; 12 with chemical subjects; 2 with textiles; 16 with mining; 5 with the wood industry; 1 with the paper and pulp industry; and 11 with topics of a miscellaneous or general character.

Standardization on an international scale of certain dimensional standards and specifications was discussed at informal meetings of the secretaries of the national standardizing bodies. The first of these meetings was held in April, 1921, in London, and the second in July, 1923, in Zurich, Switzerland. Following the latter meeting specific projects were discussed, and by special arrangement an international conference on ball bearings was held. This conference helped to bring to a satisfactory conclusion negotiations which had been carried on by mail for a number of years. It is now possible to state that there are 97 sizes and types of radial ball bearings which are recognized internationally.

A general conference on international standardization is now being discussed, and it is possible that unification of the dimensions of bolts, nuts, and wrench openings will constitute one of the projects to be discussed at that meeting.

At present there is an exchange of ideas and of new standards between all national standardization committees, and the possibility of standardization of other machine elements such as, for example, screw threads on an international basis, is also foreseen.

STANDARDIZATION OF MACHINE-TOOL ELEMENTS

At the present time, of the work accomplished by the sub-committees of certain Sectional Committees organized under the procedure of the A.E.S.C. and shown in Fig. 2, the most important thus far completed is the standardization of screw threads. This standardization was finished in the summer of 1924 under the sponsorship of the Society of Automotive Engineers and The American Society of Mechanical Engineers. It deals with pitches of screw threads, classification of screw-thread fits, tolerances and allowances for threaded parts, and gaging of threads. By the adoption of the report of this Committee, screw threads are standardized in two series: an American coarse series for general work and American fine series for work in which a finer thread is desirable, as for example in the manufacture of automobiles. The same form of thread is used in both. The adoption of standard screw threads is perhaps the most important advance in the American industrial standardization. Certainly in the mechanical industries screw threads are fundamental to design and manufacture in every field and enter into almost every kind of manufactured product and machine. In the coarse-thread series the present United States or Sellers standard of thread is supplemented by the A.S.M.E. standard below $\frac{1}{4}$ in., and the fine-thread series in the Society of Automotive Engineers series is supplemented by the A.S.M.E. fine threads. Different classes of fits—free, medium, and close—are established with corresponding numerical tolerances to provide for unavoidable inaccuracies of workmanship under practical conditions. In the foreword to its report occurs the following statement: "The Sectional Committee hopes that further steps will be taken by mutual concessions which will result in bringing together the Whitworth and the American systems of threads so as to secure interchangeability in the English-speaking world. The Committee also looks forward to the time when by conference with the standardization associations of the countries using the metric system, agreements along similar lines for metric fits and tolerances will be brought about."

Another work undertaken under the auspices of the American Engineering Standards Committee is that of standardizing small tools and machine-tool elements. This project is sponsored by the National Machine Tool Builders' Association and The American

Society of Mechanical Engineers. It deals with the standardization of work-holding and tool-holding elements of machine tools, such as T-slots, spindle noses, and machine tapers, and small tools associated therewith.

PRINCIPLES RECOMMENDED

The Central Committee met on April 26, 1922, and drew up the following rules to be used in its preliminary work:

The desirability of standardization of various machine-tool elements having been made evident, the work should be confined to the consideration of elements that affect both the user and the manufacturer. One group of these elements, is naturally made up of those connected with tool-holding and work-holding, and some of the considerations affecting these are as follows:

1 As affecting a large variety of machine tools, the T-slot should be standardized, and perhaps T-slot bolts and nuts should be standardized at the same time.

2 As affecting many different kinds of machines on which it is desirable to interchange chucks or tools, spindle ends or spindle noses (as frequently designated) should be considered.

3 As affecting the use of wrenches, and to eliminate the monkey wrench, coöperation should be freely given to the committee which is standardizing bolt heads, nuts, and wrenches.

4 The standardization of tapers should also be considered, inasmuch as it affects a variety of machines.

5 Standard sizes or ratings of machines should be established. This would be in the nature of terminology or definition, so that a purchaser would know what was meant, for instance, by a 14-in. lathe.

6 Standard sizes, or intervals of size, should be determined for different groups of machines and variances from the standard intervals should be discouraged, because multiplicity of sizes merely means additional expense to the industry with no corresponding gain to any one, either purchaser or manufacturer.

It was also recommended that the use of preferred-numbers series be promoted; these numbers to be used as nearly as possible in deciding on sizes of machines and ranges.

[1] Safety Code projects are not included in this diagram. The standard for "Screw Threads for Fire-Hose Couplings," recently approved by the A.E.S.C., is also omitted. The standard was submitted under what is known as "Rule R-4" procedure, and no sectional committee had to be organized in this case (see Fig. 1). The joint sponsors for this standard were: The A.S.M.E., the National Board of Fire Underwriters, and the National Fire Protection Association.

T-SLOT STANDARDIZATION

The Sub-Committee appointed for the standardization of T-slots has finished a preliminary report and has sent out questionnaires to the various manufacturers. It is hoped that the various machine-tool manufacturers using T-slots in their product will express their opinions as to the three specific proposals submitted.

The greatest variation in practice among the various machine-tool builders is in the width of the throat. This is obviously the most important dimension, as it is the only one that greatly affects the interchangeability of attachments and fixtures. A considerable number of manufacturers provide T-slots of the same width as the nominal diameter of the bolt, the bolt itself being slightly undersize. A still larger number provide T-slots wider (usually by 1/16 in.) than the nominal diameter of the bolt. This latter practice facilitates the use of T-nuts instead of the conventional T-bolts.

A general review of the T-slots now in use led the members of the Working Committee to believe that this standardization project should provide T-slots for bolts of the following diameters: 1/4 in., 5/16 in., 3/8 in., 7/16 in., 1/2 in., 5/8 in., 3/4 in., 7/8 in., 1 in., 1 1/4 in., and 1 1/2 in.

The dimensions themselves are given in Table 1. A nomenclature for the several T-slot dimensions was tentatively agreed upon as shown on Fig. 3.

There is no need of reviewing the arguments concerning the relative merits of the two practices for width of throat. It is sufficient to point out that the mere fact that they are established will add to the difficulties of standardization.

As a result of this difference in practice the sub-committee has under consideration the following three proposals:

1 Throat width same as nominal diameter of bolt.

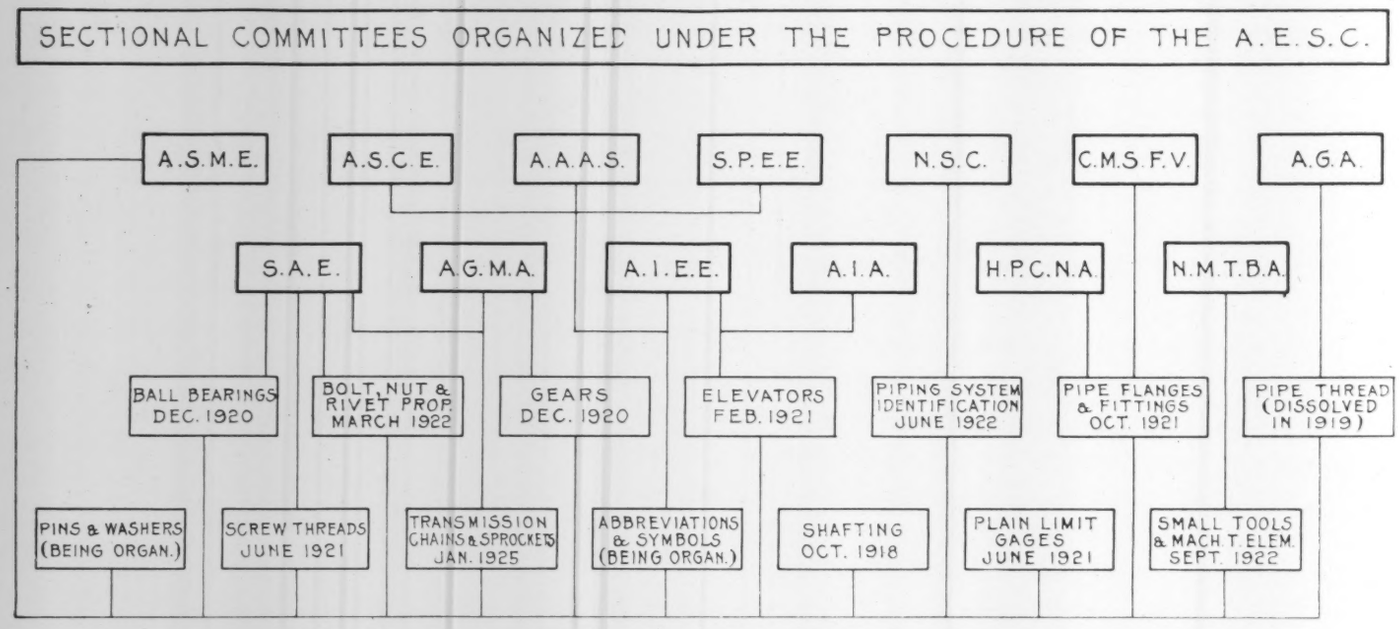

FIG. 2 PROJECTS FOR WHICH THE A.S.M.E. IS SPONSOR OR JOINT SPONSOR[1]

(A.E.S.C., American Engineering Standards Committee; A.S.M.E., American Society of Mechanical Engineers; A.S.C.E., American Society of Civil Engineers; A.A.A.S., American Association for the Advancement of Science; S.P.E.E., Society for Promotion of Engineering Education; N.S.C., National Safety Council; C.M.S.F.V., Committee of Manufacturers on Standardization of Fittings and Valves; A.G.A., American Gas Association; S.A.E., Society of Automotive Engineers; A.G.M.A., American Gear Manufacturers Association; A.I.E.E., American Institute of Electrical Engineers; A.I.A., American Institute of Architects; H.P.C.N.A., Heating & Piping Contractors National Association; N.M.T.B.A., National Machine Tool Builders Association.)

TABLE 1 DIMENSIONS FOR PROPOSED T-SLOT STANDARDS

(Letters refer to Fig. 3, all dimensions in inches)

Width of throat A		Width of head space C	Depth of head space D	Depth of throat E
No. 1	No. 2			
1/4	9/32	1/2	5/32	Not yet determined
5/16	11/32	5/8	5/32	
3/8	7/16	11/16	7/32	
7/16	1/2	13/16	7/32	
1/2	9/16	15/16	9/32	
5/8	11/16	1 3/16	13/32	
3/4	13/16	1 5/16	17/32	
7/8	15/16	1 5/8	11/16	
1	1 1/16	1 7/8	13/16	
1 1/4*	1 5/16	2 1/4	1	
1 1/2*	1 9/16	2 3/4	1 1/4	

* No standard cutters for these sizes.

2 Throat width $^1/_{32}$ in. or $^1/_{16}$ in. greater than the nominal diameter of bolt.

3 Throat width optional, leaving the manufacturer a choice between the first two proposals, according to his preference or his past practice.

The question arises why the T-slot throat was made the same width as the bolt diameter. The author has been told by men working many years in the machine-tool field that the original idea was to prevent the use of rough bolts in the T-slots of tables. In a $^5/_8$-in. slot only a finished $^5/_8$-in. diameter bolt could be used or a rough bolt of $^1/_2$ in., which generally would be too small.

Today practically all of the T-bolts used are either semi-finished or finished bolts, and therefore to give sufficient clearance for the bolt in the slot, and to avoid any sticking of the bolt, it is desirable to have the width of the T-slot larger than the bolt. It is hoped that the Committee can see its way clear to adopt the standard where the width of the T-slot is larger than that of the bolt diameter, and that it will eliminate the present practice. This is not only desirable for the simplification of this T-slot problem, but also, as the author sees it, for the moral effect it will have, because if it is not possible to agree on some standard for such a simple element as a T-slot, it certainly will be much harder and discouraging when the bigger problems of standardization are encountered which are still before us. It would also be desirable that for certain machine tools the distance between the various T-slots on the tables should be standardized so that jigs, fixtures, and vises could be interchanged between various makes of machines.

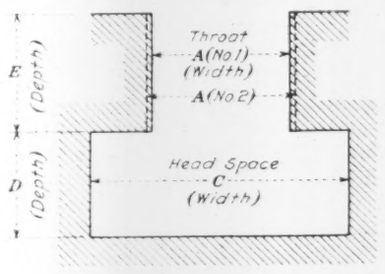

FIG. 3 PROPOSED T-SLOT STANDARD
(Dimensions are given in Table 1)

As to other work-holding devices, it would be desirable that a standard should be laid down for the dimensions of chucks, face plates, dogs, and drivers for work in lathes and grinders, etc., so that these devices could be used for the various makes of machines. This standardization should deal particularly with the dimensions of these devices at the point of their attachment to standard machine tools.

TAPER STANDARDIZATION

More complicated conditions are met with in the question of taper standardization. In October, 1922, a proposal was sent to the various machine-tool makers by the National Machine Tool Builders Association, dealing with standardization of tapers in the various machine-tool spindles. The proposal recommended the adoption of both the Brown & Sharpe and Morse tapers as the standards, supplemented by three additional sizes of larger dimension taken from the Jarno taper and changed only in the length of the shank, which was shortened. The Brown & Sharpe taper is universally used for milling machines and the Morse taper is used on drilling machines and also to quite an extent on lathes. There are, however, some manufacturers who use the Jarno standard tapers or modified Morse or Jarno tapers of their own. The Brown & Sharpe taper consists of 16 different sizes, ranging from $^1/_4$ in. to $2^1/_2$ in. in diameter, whereas there are only 8 sizes in the Morse system within the same range. There is a preference on the part of lathe and drilling-machine designers for the Jarno or Morse tapers of 0.6 in. or $^5/_8$ in. taper per foot on account of the end pressure frequently encountered by the tools on these machines, while the taper of the Brown & Sharpe system would cause the tools to stick harder and make their removal more difficult.

In the past the driving of the arbor or cutter of a milling machine was done to a certain extent by the taper shank, and therefore a better "bite" of the shank was desirable. Today all milling machines for heavier cuts use a positive drive of the arbor, and this bite or grip is therefore not so essential.

It is very likely that the final outcome of the standardization work on tapers will be the use of the two standards, the Brown & Sharpe and the Morse, and this certainly will simplify the general conditions as to arbors, shank tools, shank drills, and centers materially.

A graphic comparison between various tapers is shown in Fig. 4.

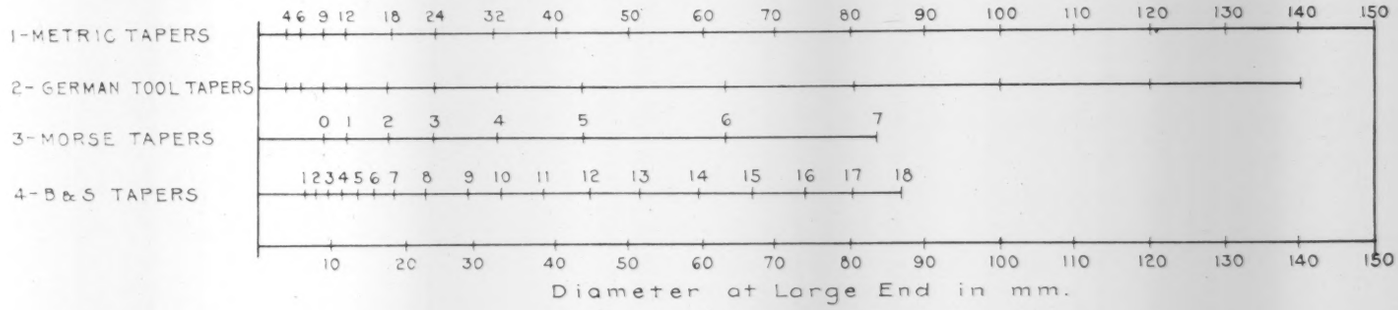

FIG. 4 COMPARATIVE DIAGRAM OF TAPERS

It is interesting to note that Germany has a series of tool tapers the middle part of which consists of Morse tapers from No. 0 to No. 6, inclusive, flanked at both ends by metric tapers.

The Swedish Industrial Standards Committee (SIS) has recently proposed that Brown & Sharpe tapers up to and including No. 16 be adopted as the Swedish standard for milling machines, and Morse tapers (extended according to the German idea) for drilling machines.

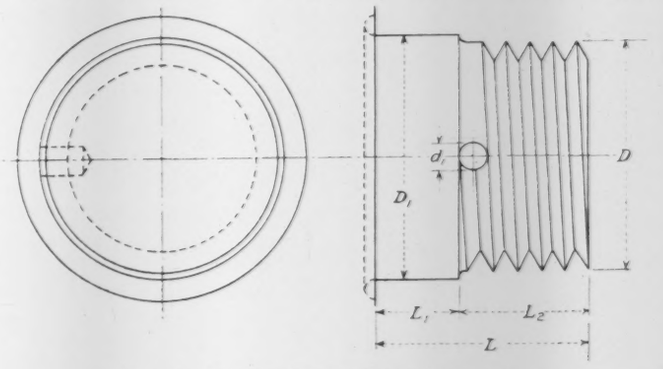

FIG. 5 GERMAN SPINDLE-NOSE STANDARD

STANDARDIZATION OF SPINDLE NOSES

A more complicated problem is that of the standardization of spindle noses. Until recent years all machine tools with a rotating spindle had the spindle nose threaded at the front for attaching either tools or work-holding devices. With the use of heavier cuts on milling machines and with the running of the spindles in both directions it was found that the old-style threaded spindle noses were not very satisfactory, and new constructions were developed and adopted by the manufacturers in this country and abroad. No two of these spindle noses are alike; some are similar in design but different in dimensions, so that for practically every make of milling machine different face mills have to be used. There is no possibility of interchanging the arbors. The result is that large numbers of duplicate tools are required in any shop where different makes of milling machines are employed. Practically the same conditions exist in the case of other machine tools such as lathes,

for example, where the spindles of various makes differ in diameter and in the number of threads. The functions of the spindle end on a lathe and on a milling machine are somewhat similar, and an attempt should be made to devise a standard for spindle noses which will be applicable to all machine tools where the functions are the same or similar. No serious objections were raised by the users of milling machines when manufacturers changed their spindle noses, and the author feels that if a real standard could be developed for these various tools, the users of machine tools would be only too glad to accept it as it would reduce considerably the number of cutters, arbors, chucks, face plates, etc., they are obliged to carry in their toolrooms. Fig. 5 shows the German recommended spindle-nose standard.

From the author's personal experience in the standardization of spindle ends at the works with which he is connected, he can say that one standard of spindle nose will cover a considerable range of sizes of machines. The Cincinnati Milling Machine Company uses on all its single-pulley and automatic machines spindle noses of exactly the same dimensions. It uses this one standard spindle nose on a No. 5 miller with 20-hp. capacity and also on a No. 1 machine with a 3-hp. motor. In all these machines the company uses a No. 14 B. & S. taper hole, so that the arbors, shell end mills, face mills, and similar tools are completely interchangeable on all sizes of its machines.

OTHER STANDARDIZATION WORK

Another sub-committee, now in formation, will deal with the standardization of lathe and planer tool holders and tool-post openings to permit the interchange of tools in lathes, shapers, and planers. It is not the intention here to recommend any particular design, but only to point out that the essential to be accomplished is to provide interchangeability for the various tools and machine elements.

Wheel collets for grinding machines are another desirable element to be standardized. A modern machine shop does not want to take a wheel off a collet before it is to be finally discarded, due to the necessity of rebalancing the wheel when it is mounted again on the collet. Therefore, for every grinding machine a number of collets should be in use. With the standardization of these wheel collets for grinding machines it would be possible to reduce the number of chucks. The author does not know of any committee that is working on this problem.

The standardization of spur, helical, herringbone, bevel, and worm gearing, covering general gear proportions, tooth form, mounting of gears, the selection of material, and the inspection of gears, is being formulated by a committee sponsored by the American Gear Manufacturers Association and the American Society of Mechanical Engineers. No doubt much benefit will be derived by machine-tool builders from this standardization of the gears used in their machines.

Sponsored by the National Machine Tool Builders Association and by the National Bureau of Casualty and Surety Underwriters, a safety code for machine tools is in preparation. This code will deal with the operation of machine tools such as lathes, shapers, gear cutters, milling machines, etc., and will no doubt serve as a guide for the machine-tool designer in properly safeguarding the operators of such machines.

A number of committees are at work on the standardization of other machine elements such as pins and washers, bolts, setscrews, nuts, fillister-head screws, wrenches, etc. Standardization of limits and tolerances for the various kinds of cylindrical machine fits, including allowances and tolerances for interchangeable manufacturing, has progressed satisfactorily. The work of classifying and fixing of standard tolerances for plain limit gages and methods for gaging these classes of fits will be completed by a committee in a very short time. The sponsor for this work is The American Society of Mechanical Engineers.

With the increase in power requirements due to the heavier cuts of machine tools, it has been found desirable in certain places to do away with ordinary keys for the mounting of members and the system of shafts with integral keys already adopted by the automobile industry will, it is hoped, more and more come into favor in the machine-tool industry. It is desirable that a standard for these such shafts be developed, for their employment would result in saving a considerable amount of money, inasmuch as standard broaches could be used in their manufacture.

The designation of sizes of machine tools by figures, such as No. 2 milling machines, 14-in. lathes or 6-ft. radial drills, does not give a true picture of the machines in question. It would be advisable to revise our method of designating machine-tool sizes in such a way as to give a better conception of capacity, and especially should the power requirement form a part of the designation.

More and more is the individual motor drive being used in machine tools, but different speeds, different sizes of frames, different shaft diameters and different voltages make the incorporation of motors into the machines very expensive and difficult. The standardization of motor frames, motor speeds, and armature-shaft diameters is very desirable indeed, and a committee of representatives of the electrical industry in coöperation with the machine-tool industry should consider this problem.[1] Just as serious as the electric-motor problem is the application of the control apparatus, some of which are of still larger dimensions than the motor itself. In a large number of cases under present conditions it is impossible to incorporate this control apparatus in the machine, and unsightly appearance generally results.

In this respect a good deal of work has been done in Germany where the author has seen planers driven by reversing motors with the control apparatus inside of the housings. In other machine tools the Germans use quite frequently barrel-shaped or flanged motors, which give the machine tools a neat appearance. The author has been informed that they have also standardized certain dimensions such as, for example, shaft diameters.

At present hardly any two factories use the same method of dimensioning drawings, the same indications as to materials, finish, tolerances, and other information such as drilling, boring, scraping, etc., and it is therefore necessary for every new employee to learn each new method. The author does not see any reason why a standard could not be adopted which would take care of the various kinds of information which a drawing is expected to give; and if such a standard were uniformly adopted, it would make it less costly for the employer and easier for a new employee to work his way into a new position, inasmuch as he would be fully acquainted with the standardized system. Incidentally the sizes of drawings could be standardized so that drawing and tracing paper of the same size and standardized cabinets for storing them could be used.[2]

CONCLUSION

The author has attempted to give a general idea of the status of the standardization of machine tools in this country at the present time and of the agencies through which this work is performed. It is desirable that this work be kept up and that through coöperation between engineers, manufacturers, and users of machine tools results be obtained which will be of benefit to the industry at large as well as to the country. Of course the individual machine-tool manufacturer has to say whether or not he wants certain elements of his products standardized. Now this standardization work is to a large measure within his control. But if he does not exercise this control, standards may be forced upon him by the users which do not meet the problems of modern machine tools and which may be very expensive to comply with.

American machine tools are known the world over for their modern design, their first-class material, and their excellent workmanship. Hence the machine-tool industry has established a high standard of performance and the designation of this standard is "Made in the United States." Let us all work together to maintain that standard.

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[1] A request has been made by the National Machine Tool Builders Association to the A.E.S.C. to take up the standardization of certain frame dimensions of electric motors. A special committee has been recently appointed which is investigating the question before calling a general conference on the subject. Questionnaires have been sent out and are being analyzed.—EDITOR.

[2] The A.E.S.C. has been recently requested by the A.S.M.E. to authorize the organization of a Sectional Committee whose duty it would be to develop standards for drawings and certain drafting-room practices. The Society has signified its willingness to act as sponsor or joint sponsor for this project. At the Main Committee meeting of the A.E.S.C. on June 11, 1925, the Chairman was authorized to call a general conference or to appoint a special committee to consider the proposed standardization.

The Ruths Steam Accumulator

Description of System and Automatic Control Valves—Application to Sugar Refinery and Steel Works Analyzed

By ALFRED J. T. TAYLOR[1] and F. A. WETTSTEIN,[2] TORONTO, CANADA

AS MANAGING director of some of the foremost plants in both the steel and paper industries in Europe, Dr. Johannes Ruths, a Swedish engineer, conducted a number of studies and tests in industrial plants, with a view to effecting the highest efficiency and production of the entire plant, and out of these investigations grew the Ruths steam accumulator system, which has been adopted by more than two hundred of the leading industrial plants in Europe and has been the subject of more than two hundred technical papers in foreign languages.

Principle of the Ruths Accumulator

The Ruths steam accumulator is based on the principle of storing in a large quantity of water under pressure and at saturation temperature the heat energy of steam, and releasing this energy in the form of steam under decreasing pressure. The accumulator is, in effect, the heat flywheel of the boiler plant. Fig. 1 is a set of curves showing the steam-storage capacity of water.

For example, if a pressure of 400 lb. in a boiler is lowered to, say, 350 lb., Fig. 1 shows that 0.8 lb. of steam will be obtained from each cubic foot of water. The Ruths steam accumulator can be arranged to work under much lower pressures, say, between 60 and 10 lb. For this pressure range the curves show a storage capacity of 4.2 lb. of steam per cubic foot of water. Thus, for the same pressure drop of 50 lb. the storage capacity of the accumulator may be five times larger than in a modern boiler for the same quantity of water. In addition, the boiler has to be built, as in this example, to withstand 400 lb. pressure and the accumulator only 60 lb. Steam-storage capacity in an accumulator can therefore be obtained much more cheaply than in a boiler. Usually large pressure fluctuations as assumed above are not allowed to take place in the boiler, and so the difference between the comparative storage capacity of boilers and accumulators is increased still further. These figures clearly show that steam boilers should be built only for the purpose of generating steam at a constant rate and that all superfluous water space should be arranged for in a separate receptacle, built for a lower pressure, in which much wider pressure fluctuations may be allowed than in the boiler.

The Ruths accumulator is built in the form of a cylindrical steel tank with hemispherical ends. The volume of the accumulator is so large in comparison with its exterior surface that an insulation of 3 to 4 in. thickness is sufficient to reduce the heat loss to a negligible amount. The accumulator is usually installed in the open air without building protection. The plant consists of two parts, the accumulator proper and the valves for its automatic regulation.

View Showing a Ruths Accumulator Erected on Top of a Building because of Limited Ground Space

Construction of the Ruths Accumulator

Fig. 2 shows a complete accumulator installation. The tank A is constructed of riveted steel plates and filled about 90 per cent full of water. Over this is a covering B of non-conducting material, with insulation blocks C covering the riveted seams of the shell, easily removable for the inspection of the seams. This lagging is protected by a light sheet-iron cover D.

The non-return valve E admits charging steam to the internal steam-distribution pipe F and the charging nozzles G, which are equipped with circulation pipes H to insure a uniform and noiseless heating of the water. Through the non-return valve I, the discharge of steam takes place. A De Laval nozzle K limits, in case of emergency such as a rupture in the steam piping, the maximum discharge of steam from the accumulator to an amount which will not allow priming.

A water column L and feed valves M are provided for reading and adjusting the water level in the accumulator. Condensation of steam in the accumulator would tend to increase the average water level, but the fact that the volume of the steam discharged is greater than that which enters the accumulator, due to decreased density at the lower discharge pressure, counterbalances the effect of condensation so well that it is only necessary in practice to readjust the water level at intervals of several weeks.

Automatic Control

Of the highest importance in the proper functioning of the accumulator system is the regulating equipment which, by analogy, may be called the steam switchboard. In Fig. 2 this is shown as consisting of the two automatic regulating valves V_1 and V_2, which control the charging and discharging of the accumulator and maintain constant pressures in the factory steam mains. In the present case it may be assumed that valve V_1 is connected to the boiler main N, and is controlled by the boiler pressure in such a way as to maintain it constant. That is, it acts as an overflow valve for the boiler, being set for a pressure slightly lower than the safety valves. The popping of the safety valves on the boilers will always be prevented, and when steam is generated in excess of the pressure for which valve is adjusted it will automatically pass through this valve into the accumulator line O. A reducing valve V_2 maintains a constant pressure in line P leading to the steam consumers. According to whether at a given moment more or less steam is passed through valve V_1 than through valve V_2, the accumulator will be charged or discharged.

In case the accumulator should happen to be charged up to its maximum pressure, V_1 acts as a maximum-pressure valve and will shut off further steam supply to the accumulator. On the other hand, if the accumulator should happen to be completely discharged, V_1 acts as a reducing valve securing sufficient supply of steam to the secondary steam line P, despite the fact that the accumulator is discharged.

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[1] Combustion Engineering, Ltd. Mem. A.S.M.E.

[2] Combustion Engineering, Ltd.

Presented at a meeting of the Ontario Local Section of The American Society of Mechanical Engineers, Toronto, December 17, 1924. Slightly abridged.

In order to obtain correct coöperation of the different functions of these control valves, an extreme sensitiveness of the pressure regulation is required. The principle of the relay developed for these valves is shown in Fig. 3. The motion of the steel diaphragm A, which is exposed to the steam pressure admitted through pipe B, is transmitted by rod C to the lever D, which is held by spring

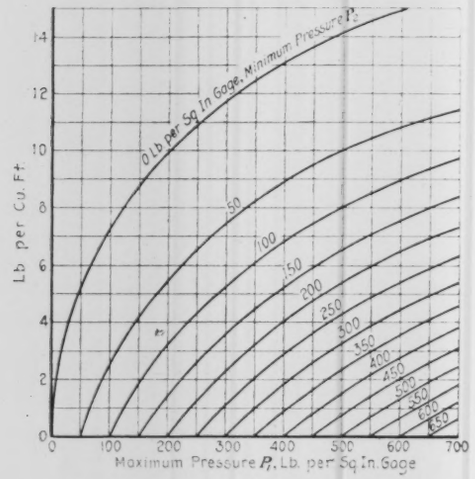

FIG. 1 DIAGRAM SHOWING THE AMOUNT OF STEAM EVAPORATED FROM 1 CU. FT. OF WATER WHEN PRESSURE IS DECREASED FROM p_1 TO p_2

by means of the handwheel shown on the top of the valve. All moving parts of the valve are working in a closed oil system, so that wear and attendance are practically negligible.

APPLICATION OF THE RUTHS ACCUMULATOR TO A SUGAR REFINERY

The following proposed Ruths steam accumulator installation for a sugar refinery may apply to any other industrial plant consuming steam for process work and generating power.

Process steam is required in this plant at 10 lb. pressure for triple effects, heating, etc., and at 80 lb. pressure chiefly for the sugar pans. The entire consumption of steam is shown in Fig. 5. The demand for steam is changing constantly and within short periods through a wide range. The steam consumption averages 125,000 lb. per hr. and fluctuates between 70,000 and 180,000 lb. per hr. The demand for power of the entire refinery is fairly constant and amounts to about 2000 kw.

The layout of the proposed installation is shown in Fig. 6. The boilers are designed for a pressure of 350 lb. and a superheat of 150 deg. fahr. Two 1000-kw. non-condensing turbines equipped with speed governors will expand the process steam from 350 to 80 lb. pressure and supply the plant with electrical current. A compound regulating valve V_1 is arranged to bypass process steam in excess of that required for the generation of power.

The accumulator works through a pressure range of from 80 to 10 lb. and has a storage capacity of 50,000 lb. of steam, a volume of 12,000 cu. ft., a diameter of 16 ft., a total length of 66 ft., and is connected to the steam system by means of the two regulating valves, V_2 and V_3.

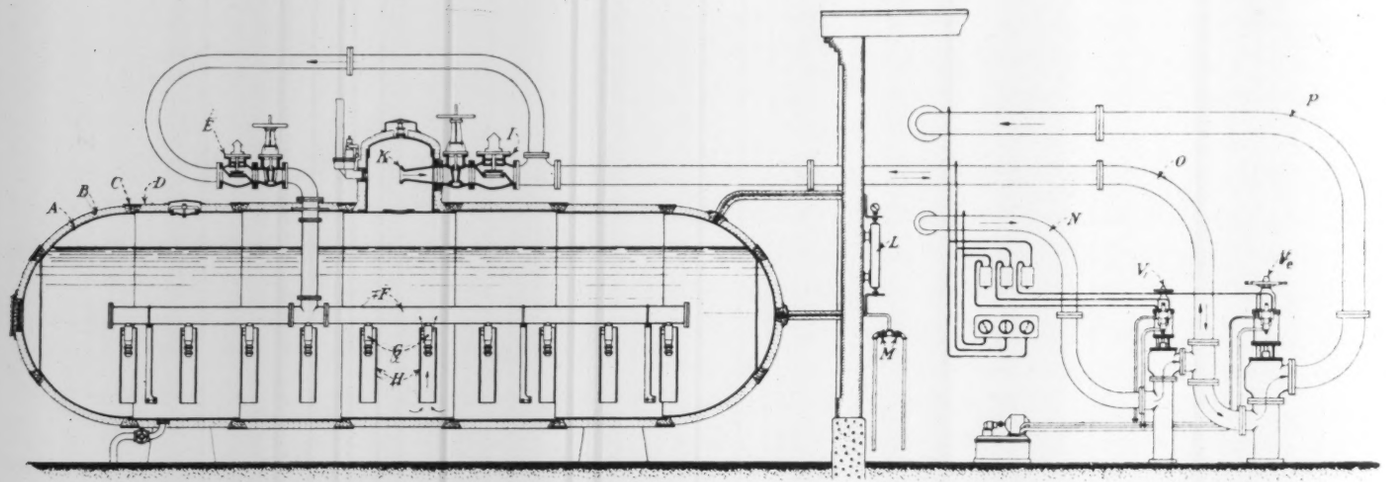

FIG. 2 RUTHS ACCUMULATOR INSTALLATION, SHOWING SECTION THROUGH ACCUMULATOR AND STEAM SWITCHBOARD TO THE RIGHT

E against edge F. The lower, fork-shaped end of lever D is covering, more or less, two opposite orifices G in oil pipe H. Oil is supplied by a small motor-driven pump under constant pressure through pipe I and is throttled at K. A small movement of diaphragm A is magnified about fifty times by lever D, this changing the size of the two orifices G, and hence the pressure in pipe H, resulting in a certain movement of the spring-loaded piston L. The main features to which the success of this pressure relay are due are, besides the steel diaphragm, the arrangement of fork D which is moving in a right angle to the oil jets through orifices G so that fork D is perfectly balanced, and further the absence of all friction in the entire relay.

The movement of piston L is used to control by means of a pilot valve the supply of pressure oil to a servo-motor actuating the regulating valve. Fig. 4 is a section through a complete regulating valve, which is equipped also with the return motion required for stability of regulation. The different parts of the relay are marked with the same letters as in Fig. 3.

These valves can be adjusted to regulate any steam pressure and to keep such pressure constant within a range of less than one pound. The time required for opening and closing may be regulated between one-fifth of a second and sixty seconds. Further, these valves may be closed instantaneously by relieving the oil by turning the lever N, and after doing so the valve may be operated by hand

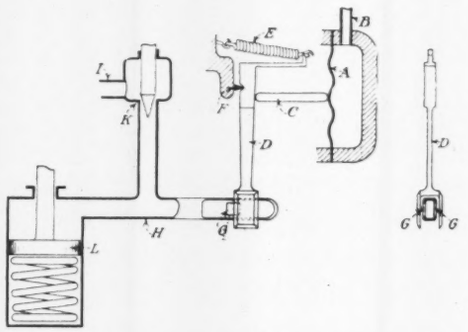

FIG. 3 PRINCIPLE OF AVA PRESSURE RELAY

The sugar pans are connected to both the 80-lb. and 10-lb. main, the cooking process starting with 10-lb. and continuing with 80-lb. steam. All the other steam consumers, such as triple effects, evaporators, heating system, etc., are connected to the 10-lb. steam main.

In the operation of the plant a constant amount of steam corresponding to the average steam consumption of the refinery is generated in the boilers. All steam which is not allowed to pass through the turbines is passed through regulating valve V_1, which

acts as an overflow valve for the boiler-house main and maintains the boiler pressure automatically and constantly just below the point for which the safety valves are set. The 80-lb. steam main receives steam from the non-condensing turbines and through regulating valve V_1 equal to the constant steam output of the boiler. A varying amount of steam as required is supplied from the 80-lb. main to the sugar pans and the rest is automatically passed through regulating valve V_2 which acts as an overflow valve for the 80-lb. main and maintains it at constant pressure. The reducing valve V_3 admits enough steam to the low-pressure main to maintain 10 lb. pressure in it.

If, at a certain moment, the steam consumption of the refinery corresponds to the total average quantity of steam supplied by the boilers, an equal amount of steam will pass through both regulating valves V_2 and V_3 and no steam will pass to or from the accumulator. Assuming, on the other hand, that a peak occurs in the consumption of steam through the 80-lb. main to the sugar pans, valve V_2 will maintain the 80-lb. pressure, and since less steam is now supplied through it to the low-pressure line, the accumulator will supply sufficient steam through V_3 to maintain a constant pressure in the 10-lb. main. If the steam consumption in the 80-lb. line again decreases, or even drops to zero, valve V_2 will relieve all excess steam from the 80-lb. main and pass it to the accumulator where it is stored until the next peak occurs. All fluctuations in the consumption of 10-lb. steam are directly taken care of by a variable discharge from the accumulator through V_3.

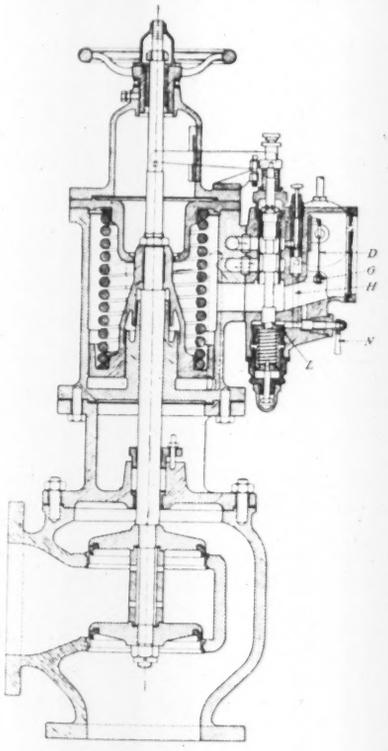

FIG. 4 SECTION THROUGH AVA PRESSURE-REGULATING VALVE

Thus all fluctuations in the consumption of steam, wherever they occur, are automatically taken care of by the accumulator and will not be felt either at the non-condensing turbines or in the boiler house. The boiler pressure will be automatically maintained constant and will therefore no longer serve as a guide by which to regulate the fires. The firemen will maintain the fires constant so long as the accumulator pressure, which is indicated in the boiler house by a master gage, is within normal limits. Changes in accumulator pressure will be small and may be effected gradually, due to the large storage capacity of the accumulator.

BENEFITS

A close analysis of the benefits of an accumulator installation like the above is difficult if such benefits have to be expressed in terms of dollars and cents saved. The most important advantage, and the one most difficult to appraise, is the beneficial effect of the system upon the quantity and quality of production. Just as constant voltage is an indispensable requirement in an electrical system, so constant steam pressure and temperature are indispensable for uninterrupted production and uniform quality in the goods produced. The accumulator's ability to deliver large quantities of steam at constant pressures is practically limited only by the size of the steam piping, and the steam switchboard provides for automatic distribution.

Without an accumulator the boiler plant has to be built to provide for the peak loads, whereas with an accumulator the boiler plant need have only sufficient capacity for the average steam consumption. In the present example, three boilers of 700 hp. at about 200 per cent of rating would be able to take care of the average steam load of 120,000 to 130,000 lb. per hr. Without an accumulator an additional boiler of 700 hp. would be required to provide for the peak loads, which go as high as 180,000 lb. per hr., or 50,000 lb. per hr. above the average. The saving in cost for a completely equipped boiler of 700 hp. will more than pay for the cost of the installation of the entire accumulator system.

During periods of low steam consumption when sufficient power could not be obtained from the process steam in the non-condensing turbines, it would be necessary without an accumulator to install bleeder turbines instead of non-condensing turbines so that with decreasing consumption of process steam the deficiency in the output of non-condensing power could be made up in the low-pressure stage of the bleeder turbine. Not only would the additional cost of the bleeder turbine with low-pressure stage, condenser, and condenser pumps be considerably more than the cost of non-

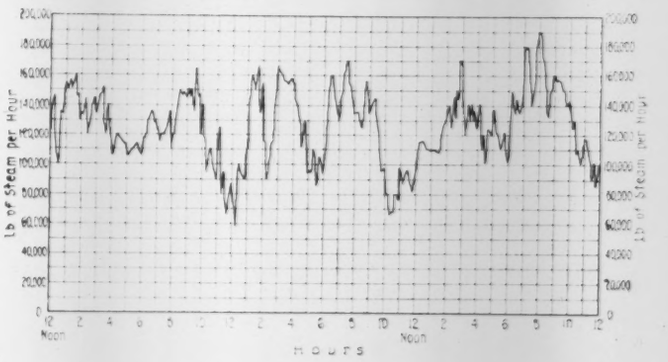

FIG. 5 STEAM CONSUMPTION IN A SUGAR REFINERY

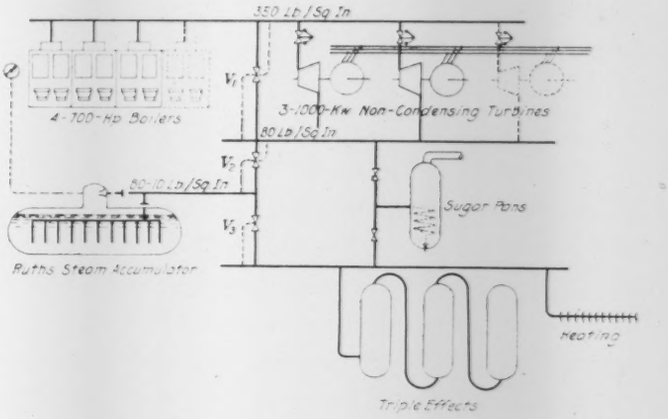

FIG. 6 ARRANGEMENT OF RUTHS ACCUMULATOR IN A SUGAR REFINERY

condensing turbines, but such a plant would be much more complicated in operation.

Further, with an accumulator the output of cheap, non-condensing power will be increased. Without an accumulator, steam would at certain times have to be bypassed the turbines, and at other times not enough process steam would be consumed to generate sufficient power in the turbines. The accumulator makes it possible to pass all of the process steam as a continuous and constant flow through the turbines. This, and the fact that pressure and superheat at the throttle of the turbines are constantly being maintained at their highest point, will result in highest efficiency of the turbines and in maximum output of power from the process steam.

It is a well-established fact that boiler efficiency over a considerable range of rating varies comparatively little, provided the efficiencies are determined during periods of constant operation, but the fact that efficiency during actual operation never attains the test efficiency has been confirmed by an increased boiler efficiency in plants which are equipped with accumulators. With an accumulator, the boilers may continuously operate under the most favorable test conditions and their operation is independent of that of the manufacturing plant and the power plant.

With an accumulator, forcing of the boilers will be avoided. Brickwork and boiler will be kept at even temperature and will

be released from the constant expansion and contraction which accompanies a fluctuating load. This will reduce to a minimum the upkeep cost for boilers, furnaces, and firing equipment.

Since the operation of the accumulator installation is entirely automatic and the operation of the boiler house and power plant are greatly simplified, a saving in labor cost will result.

Taking everything into consideration, both the capital and operating costs of a new steam power plant will be considerably reduced if the Ruths steam accumulator system is adopted. On the other hand, if the accumulator is installed in an existing plant, the other savings, as analyzed above, will pay for the installation in a short time.

FIELD OF THE RUTHS STEAM ACCUMULATOR

The Ruths steam accumulator system has thus far found its widest application in the pulp and paper industry, textile industry, chemical industry, sugar factories, and other industries consuming steam for process work. In principle, the problem of heat and power production in all of these industries is similar to that described in the above example for a sugar refinery.

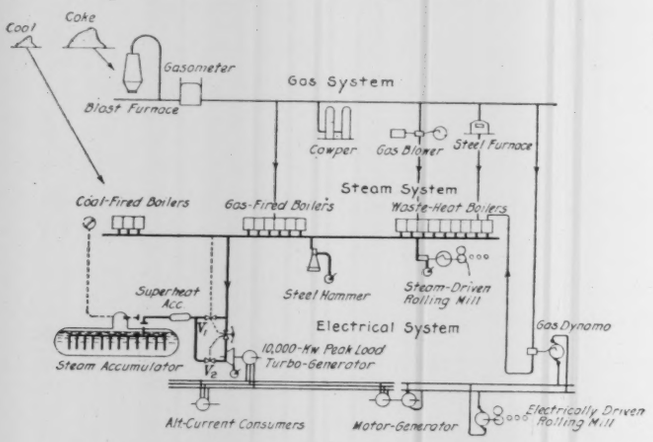

FIG. 7 ARRANGEMENT OF RUTHS ACCUMULATOR IN AN IRON AND STEEL WORKS

A somewhat different problem has to be solved for the application of the accumulator system to power stations for industries which are chiefly consuming power and using little or no steam for process work. Here the accumulator has to deliver steam to the turbines. The accumulator, as described above, delivers dry saturated steam, whereas it is desirable that the steam delivered to steam turbines be superheated. This problem has been solved by adding, in series with the ordinary accumulator, a second accumulator for storing the superheat. This superheat accumulator works on the same principle as the well-known Siemens regenerative heater, and for the superheat storing medium uses plates of pig iron.

The connection of an accumulator either to the first stage or to an intermediate stage of a steam turbine will not affect the overall efficiency of the turbine. A small loss of power, due to a certain pressure drop in the comparatively small amounts of steam passing through the accumulator, is counterbalanced by an increased efficiency due to the pressure and superheat at the turbine throttle being constantly maintained at the highest possible point.

An installation of this kind which has been proposed for an iron and steel works on the continent, is shown diagramatically in Fig. 7.

APPLICATION OF THE RUTHS ACCUMULATOR TO AN IRON AND STEEL WORKS

The energy required in the entire iron and steel works is supplied mainly by the coke with which the blast furnaces are charged. A comparatively small amount of coke gas is used in the steel furnaces and only a few per cent of the total energy is supplied by coal-fired steam boilers.

Three blast furnaces are operated with an output of approximately 1500 gross tons per 24 hours. In the blast-furnace gas is contained about 63 per cent of the heat supplied with the coke. This gas is primarily used in the cowpers for preheating the air required for the blast furnaces, in steel furnaces, in gas engines producing about 7500 kw. for driving air blowers, and in another group of gas engines coupled with direct-current generators and generating about 12,000 kw. After all these consumers are satisfied, the remaining surplus of blast-furnace gas is used in gas-fired boilers for the generation of steam. Large amounts of steam are also obtained indirectly by recovering waste heat from steel furnaces, air blowers, and gas dynamos.

This steam energy in turn is converted into mechanical energy in steel hammers and in steam engines driving rolling mills, and another part is converted in alternating-current turbo-generators into electrical energy. The alternating- and direct-current lines are connected by means of motor-generator sets. The largest consumers of electrical energy are electrically driven rolling mills. Obviously, part of the energy supplied with the coke is transformed into several different forms before it is finally applied and allowed to waste, and an interruption of the flow of energy in one department will necessarily affect many other departments, so that waste of energy, loss of production, or both will result.

However, large fluctuations, which cannot be prevented, occur in the production of blast-furnace gas and in the consumption of energy. There are also fluctuations in the consumption of steam in 24 hours caused by the rolling mills, the steel hammers, presses, etc., as shown in the lower curve of Fig. 8. The average consumption is about 125,000 lb. per hr.; and a minimum of 30,000 may be followed immediately by a maximum of 200,000 lb. per hr. Due to variations in supply and demand of steam, a large coal-fired boiler house has been provided with the purpose of equalization, but the fluctuations are of such a magnitude and occur so suddenly that operating conditions are extremely difficult, and it has been estimated that about 15 per cent of the blast-furnace gas has to be wasted due to the difference existing between supply and demand. Further, careful tests have shown that the efficiency of the gas- and coal-fired boilers under actual operating conditions is about 55 per cent, whereas an efficiency of 76 per cent was obtained with tests during which the boilers were fired at a constant rating. This would mean a saving in fuel of 27.6 per cent.

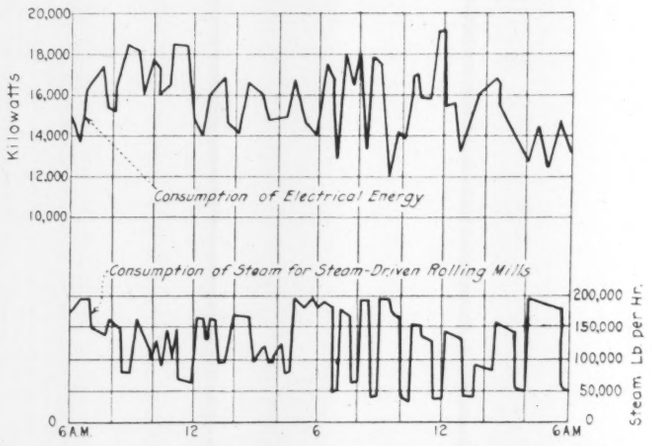

FIG. 8 STEAM AND POWER CONSUMPTION OF AN IRON AND STEEL WORKS

Another difficulty is caused by the varying demand for electrical energy shown by the upper curve in Fig. 8. The average demand is approximately 16,000 kw. with fluctuations going 4000 kw. below and above this amount. About 12,000 kw. on the average is supplied by the gas dynamos and the rest, or about 4000 kw., is generated in turbo-generators. Since it is difficult to regulate the load of gas engines in wide limits, it is desirable to take as much as possible of the fluctuations with the steam turbines. This, on the other hand, increases the difficulties in the steam system which have been described above.

From the foregoing it will be understood that very large savings and improvements in operation and increase of production would be obtained with a system allowing continuous operation at constant ratings of the gas dynamos and the coal-, gas-, and waste-heat boilers, and one which would take care of excess energy during periods of large supply and low consumption and would continuously secure an abundant supply of steam and electrical energy.

This is made possible with the Ruths accumulator installation. This installation consists of two Ruths accumulators, one superheat accumulator, and a 10,000-kw. peak-load turbine. This system is capable of storing an amount of energy as contained in 60,000 lb. of steam, and it can deliver this energy in the form of an electrical peak load of 4000 kw-hr. The two steam accumulators each have a volume of 6500 cu. ft., a diameter of 12 ft., and a total length of 60 ft. The superheat accumulator has a volume of 1000 cu. ft., a diameter of 6 ft., and a length of 35 ft., and contains 300,000 lb. of pig iron.

The accumulators and turbine are connected in the way shown in Fig. 7 to a steam main carrying a pressure of 200 lb. and connecting the boiler plants with each other. An excess of steam in this main will cause the regulating valve V_1, which works as an overflow valve for the 200-lb. pressure, to open. The surplus of steam will then first pass to the superheat accumulator, where the superheat is stored, and saturated steam will be passed on and stored in the steam accumulators. On the other hand, with a low supply of steam or large consumption of electrical energy, the regulating valve V_1 will close and the speed governor of the turbine will first admit all of the available live steam to the turbine and then will open valve V_2. Steam will be discharged from the accumulator, superheated while passing through the superheat accumulator, and admitted through valve V_2 to the turbine. The accumulators are designed to work in the pressure range from 200 to 60 lb., and the steam from the accumulators will therefore be admitted by valve V_2 to a later stage of the turbine than the live steam which simultaneously is admitted to the first stage of the turbine.

This system will take care of all the steam supplied by the waste-heat and gas-fired steam boilers, it will automatically maintain a constant pressure of 200 lb. in the steam main, and it will keep sufficient steam back in this line for the demands of the steam-driven rolling mills, steel hammers, etc. The accumulator system will further allow the gas dynamos to operate at a constant and economical load, producing about 12,000 kw. The peak-load turbine will, with the accumulators, take over the rest of the electrical load, which varies from 1000 up to 9000 kw. The coal-fired boilers may be fired at a constant rating. Their load will only have to be changed in case the accumulator pressure, which is indicated in the boiler house by a master gage, tends to reach its upper or lower limit, and such occasional changes may further be effected gradually.

The accumulator installation will pay for itself in a short time by the savings effected and the general advantages obtained. It will take care of peak loads up to 4000 kw. above the average consumption and replace a corresponding amount of boiler-house capacity. It will do away with most of wastes of the gas- and coal-fired boilers and the gas engines, and will allow boilers and gas engines to operate at constant rating and highest efficiency. It will act as a flywheel for the entire works, allowing continuous and uniform production by taking up automatically excess energy and supplying it again during peak loads.

Short-Time Malleableizing of Cast Iron

By H. A. SCHWARTZ,[1] CLEVELAND, OHIO

FROM time to time one hears that malleableizing of cast iron can be accomplished in a few days or hours, and that by this method castings can be produced equal in tensile strength and elongation to castings malleableized for the usual length of time. Thus far no proof has been submitted that such short-time malleableizing can be successfully accomplished under operating conditions.

The conversion of hard iron into malleable is accomplished, in essence, by a process involving two stages. First, the castings are maintained at a fairly high and fairly constant temperature, approximating 900 deg. cent. (1652 deg. fahr.). During this stage of the process the cementite of the casting goes into solution, and somewhat more than the equivalent amount of free carbon separates. The reaction begins slowly, soon increases in velocity for a time, and then proceeds more and more slowly until equilibrium is reached, when the metal consists of free carbon and a saturated solution of carbon, in some form, in equilibrium therewith.

It is well known that the higher the temperature, the more rapidly is carbon deposited, the sooner is equilibrium reached, and the more carbon is left in solution. The metal is then cooled to below its A_1 point, at about 760 deg. cent. (1400 deg. fahr.). As the temperature falls, the solubility of carbon decreases, and cooling can be carried on no faster than at a rate permitting this excess carbon to separate. At A_1 the solubility suddenly falls to zero, and consequently a certain definite time must be permitted at a temperature somewhat below A_1 to let the last one-half per cent or so of carbon crystallize. Graphitizing rates have been accurately studied by many observers, and the effect of temperature and of silicon content in accelerating the reaction is well known.

It is equally well known that there are limits to both temperature and silicon content which, when exceeded, very seriously interfere with the quality of the resulting product. The practice of most manufacturers is already to take advantage of both these factors, as far as is consistent with safety.

It is quite true that such metal can be passed through a heat treatment calculated to produce complete graphitization in about forty hours by working on small pieces and using a dangerously high maximum. The problem is, however, very different when working on a commercial scale. Few furnaces will heat all parts of their charge to full temperature as rapidly as in forty-eight hours, due to questions of thermal conductivity entirely, and also few furnaces are uniform in maximum temperature at all points within, say, 50 to 100 deg. cent. (90 to 180 deg. fahr.). It follows, therefore, that in practice, the heat-treatment time must be adapted to a temperature, say, 100 deg. cent. (180 deg. fahr.) lower than the highest it is safe to apply. The effect of this is a very large time increase.

The cooling of a heavy charge as rapidly as one might wish from A_1 to room temperature also presents considerable practical difficulty. In addition, at all stages of the heat treatment a sufficient safety factor for unexpected variations in operating conditions must be provided. Any attempt to work on very small lots of castings in order to obviate these thermal difficulties would cost more than could be saved by the decreased time.

The limitations on annealing rate will be seen to be very largely of engineering rather than metallurgical character. The continuous furnace has operated to improve matters to some extent, although the effects due to heat capacity and diffusivity of the large masses of pots and castings remain to a considerable degree. There seems relatively little prospect of further improvement in the metallurgy of the process. About 75 of the 92 possible elements have been studied with relation to their effect on graphitizing rate. A very limited number hold out promise of utility in this direction. It is very unlikely that any new and ingenious thermal cycles will alter the minimum time now requisite for the process as a whole.

A few processes involving the casting of relatively very high-silicon alloys in chill molds (to decrease primary graphitization) and subsequent heat treatment to complete the reaction rapidly (because of the high silicon content), have been suggested and, indeed, practiced in another connection. Such material, however, possesses few, if any, of the properties valued in malleable castings.

The author has had a somewhat intimate connection with the problem for twenty years, and can see nothing in the present state of metallurgical knowledge to warrant a hope for a large-scale commercial production of high-grade malleable castings in much shorter annealing times than at present. Fully ten years ago he was personally conversant with an emergency practice turning out malleable on an 84-hour cycle, commercially, on exactly the principles now advocated for reductions in this time. The quality of the product was, however, too erratic to justify continuing the practice.

[1] Manager of Research, National Malleable and Steel Castings Co. Mem. A.S.M.E.

Presented at a meeting of the Hartford Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Hartford, Conn., April 7, 1925.

A National Apprenticeship Program

The Apprenticeship System of the Santa Fe Railway—The Place of Vocational Schools in the District Apprenticeship Plan—Discussion of the Milwaukee Coöperative Plan

A LIVELY interest was shown in the papers read at the Apprenticeship Session, held under the auspices of the Committee on Education and Training for the Industries, at the Spring Meeting, Milwaukee, Wis., May 21, 1925, of the A.S.M.E. Dean R. L. Sackett, of Pennsylvania State College and member of the Committee, acted as chairman of the session. Harold S. Falk,[1] presented the major paper entitled, A National Apprenticeship Program. F. W. Thomas read a discussion on The Place of Railroad Apprenticeship in a National Apprenticeship Plan, and R. L. Cooley spoke on The Place of Vocational Schools in the District Apprenticeship Plan. These papers, with the exception of that by Harold S. Falk, which appeared in an earlier issue[2] of MECHANICAL ENGINEERING, and the general discussion on all the papers, appear below in abridged form.

The Place of Railroad Apprenticeship in a National Apprenticeship Plan

BY F. W. THOMAS,[3] TOPEKA, KAN.

SOME efforts were made, during the control of the railroads by the Federal Government to require all railroads to establish a modern method of training apprentices. Not much was accomplished, but there is no doubt but that a standard and uniform method could be evolved for the training of apprentices by the railroads if the methods were sufficiently flexible to suit the peculiarities of the various railroads.

While the general plan would be applicable to manufacturing plants, the latter do not require as high-grade mechanics as the railroads, for, on account of the preponderance of duplication prevalent in manufacturing plants, they are more concerned in securing a specialist, a man who is very adept at one operation, while the railroad-shop or roundhouse mechanic may in a day engage in a dozen entirely different operations, each requiring a complete knowledge and skill. A production plant wants a man who can successfully operate a lathe, turning out the same product day after day; but in a railroad repair shop this man must be equally proficient in turning, boring, chucking, or facing, or even in converting the lathe into a milling machine, and must be able to run a planer, a slotter, or perform erecting or floor work with equal proficiency.

The training of apprentices on the Santa Fe Railway has become such a fixture from long usage as to remove it from the so-called experimental stage. It is as much a part of our shops as our power house, or our tool room. No shop can operate without power to drive its machinery or lights to illuminate its buildings, nor can it operate without some department to make or maintain tools, jigs, or devices, for the machines and men. Neither can a plant be operated without men. In fact, the human hand is far more essential. The introduction of more complicated machinery and devices makes it all the more imperative to have a trained hand and brain to operate them successfully.

From what source can the necessary skilled hands be recruited to secure from these highly complicated, high-priced machines, a commensurate output? Recruiting may not be so difficult with the so-called production plants, where a workman becomes an automaton, producing a part, or performing one operation on a part day after day, but in a railway shop or repair shop, a mechanic must be a mechanic in every sense, in every way.

For several years prior to 1907 the Santa Fe Railway was in straits continuously for skilled men. So we began that year in a small way, and inaugurated our present apprentice system, spreading out gradually to all mechanical points from Chicago to the Golden Gate, from Denver to the Gulf of Mexico. We began to enjoy its benefits at once, and soon were "sitting pretty" as far as mechanics for our shops were concerned.

Other roads have apprentice-training systems, but I am going to confine my discussion to the Santa Fe system. We take boys between 16 and 22, good, healthy, alert boys who really want to learn a trade. We require a personal interview. The boy must have a grammar-school or preferably high-school education. He must pass a medical examination before a company surgeon. He must indenture himself with the consent and signed approval of his parents or guardian. The signature of the master mechanic, or superintendent of shops, makes the contract. The contract finally goes to the supervisor of apprentices for his personal signature and to see that all the requirements are complied with. This completes the preliminaries. We neither ask for nor require reference or character letters. We employ the boy upon his own recommendation and the result of our personal interview.

The boy now goes in the shop to begin his course of training, a regularly designated apprentice-shop instructor taking him in hand. He is given a locker, tool checks, and a time card. He then begins his regular, productive, useful work. A schedule of work is made for each shop, suitable for the local condition. Every machine, bench, or floor job carries its assignment. The work in this schedule may not come in rotation or in natural sequence but the boy will get his allotted time on each. Changes of work is left entirely to the instructor, for he is solely responsible for the boy's training. At the end of his indentured time, the boy, if he is a boilermaker apprentice, will know a boiler from the ashpan to the smokestack, know each part by its correct name and its functions, know how to lay out each sheet, develop it, roll up, rivet, and weld it into place, to stay it, to test it, and will be familiar with all the company and Federal rules governing the manufacture and maintenance of boilers. In fact, he is a real boilermaker. So also is it with machinists, blacksmiths, carmen, patternmakers, pipe fitters, etc.

We want our apprentices to become the most intelligent mechanics of their trade anywhere, so we endeavor to train the mind along with the hands. We have at each of our mechanical points (43 in number) schools where we teach mechanical and free-hand drawing, shop mathematics, company and Federal rules pertaining to the trade, Federal and state laws of the trade, standard shop practices, and other subjects supplementary to the practical shop features.

The railroad company provides the schoolroom, located in the midst of the shop buildings, equipped and dedicated to the apprentices. Drawing instruments, models, textbooks, stationery, etc. are furnished free, and an instructor, theoretically and practically skilled and trained, presides over this schoolroom. The apprentice is required to attend a two-hour session, two days each week, 208 hours per year, or 832 for his four-year apprenticeship, and is paid his regular shop rate of pay while attending.

The lesson or instruction sheets are of our own editing and printing and are kept up to date. Quizzes are given from time to time to each apprentice on some branch of his work in the shop. He roughs out the answers on a scratch pad and gives them to the shop instructor, who corrects them. The apprentice then takes these back to his drawing board and neatly prints out the final answers.

Regular apprentices serve four years or eight periods of 1160 hours each, a total of 9280 hours. Helper apprentices serve three years, or a total of 6960 hours. Special carman apprentices serve three years or 6960 hours. The rate of pay varies according to trades and class of apprentices. Regular four-year apprentices begin at 31 cents per hour, carmen at 44 cents per hour, and special apprentices at 57 cents, and each receives an increase of $2\frac{1}{2}$ cents per hour every six months.

Apprentices must have a standard set of tools for their trade. These are purchased through the company at wholesale prices and the apprentice pays for them in small monthly payments. The company provides a tool box free of charge.

One difficult feature in the early days of our present system was getting a fair and impartial estimate of the boy. We established a

[1] Vice-President, Falk Corporation, Milwaukee, Wis. Mem. A.S.M.E.
[2] MECHANICAL ENGINEERING, vol. 47, no. 5, May, 1925, p. 416.
[3] Supervisor of Apprentices, Atchison, Topeka & Santa Fe Ry. Co.

board to pass upon each apprentice each month during his probationary period of the first six months, and every six months afterwards or as often as individual cases demand. This board is composed of general foremen, department and gang foremen, and the shop and school instructors. They pass on the fitness of the boy to remain and continue his apprenticeship, recommend discipline, suggest means to improve any weakness that may be evident, and advertise the strong, aggressive, industrious boys, especially emphasizing qualities of leadership which may be evident. This is wonderfully helpful in training and developing a young boy.

We have many small points employing from five or six to ten apprentices. Generally these are sons of employees. We are anxious to have the coöperation of the parents especially during the first year, so we like to keep the boy near his home. To care for the small places, traveling instructors visit the places each week, generally spending two days. After a given time we transfer this boy to a larger shop where the advantages are more extensive, and in turn send the boys from the larger shops out to these smaller places generally for roundhouse and enginehouse experience. We consider no boy can be a real railroad machinist, boilermaker, or sheet-metal worker until he has had his six months' work in the roundhouse.

What have we received in return for all our labor and expenditures in training these boys? Ten years after we started we were making all the mechanics we needed. The Topeka shops, the largest in the system, up the entrance of our country in the war, had not employed a mechanic from the outside for more than two years. Think of a railroad shop employing 3000 men making all its own skilled mechanics, men familiar with the shops, methods, standards and practices, clean-cut young men, full of life, energy, and ambition!

From the ranks of our graduate apprentices we recruit draftsmen for our drawing work, assistants in the test department, assistants for staff duties, and have the following in line duty among our supervisory forces:

Division master mechanics	7
Division and general foremen	23
Roundhouse foremen	16
Assistant roundhouse and roundhouse gang foreman	63
Machine and erecting foremen	38
Boiler foremen	18
Car foremen	6
Miscellaneous foremen	7
Miscellaneous positions	16
Apprentice instructors	46
Total	240

In conclusion let me say that the greatest of all problems is the human one—securing, training, and developing the human hand to make possible the full use of your genius in applying it to the enjoyment of society, and without which your efforts will fail.

The Place of Vocational Schools in the District Apprenticeship Plan

By R. L. COOLEY,[1] MILWAUKEE, WIS.

IN MILWAUKEE there are about 90,000 young people in elementary and parochial schools, both public and private, and approximately 10,000 in the high school, excluding the technical high school, the trade schools, and the full-time schools. But not in the elementary schools, nor in the high schools, nor in the higher schools and universities are 39,000 other young people between the ages of fourteen and twenty. They are largely in some form of employment, or they are idle, but they are all in the formative years of their lives when the sort of development they undergo will determine to what economic or social plane they will attain.

The Santa Fe and the metal trades of Milwaukee may operate excellent apprenticeship systems, but unless society as a whole does what it can for all young people, neither the Santa Fe nor the metal trades of Milwaukee will prosper as they might.

Milwaukee is approaching the apprenticeship problem by the method of part time in trade, commerce, or industry, and part time in vocational school during the formative period of life. We are living in a world in which training and intelligence are needed more and more. There is a greater need for apprenticeship because of the inadequacy of the full-time school.

In Milwaukee all young people over fourteen years of age who have completed the eighth grade, or who have spent nine years in an effort to complete it, are permitted to enter employment on half-time until they reach the age of sixteen. After sixteen years of age they may continue in employment until eighteen, attending school eight hours a week. After reaching the age of sixteen they may enter a legal apprenticeship, attending school during the daytime four hours per week for the first two years of the contract.

When a trade school was opened in the city of Milwaukee offering four-year courses, attendance was limited by the fact that the majority of those young people aspiring to service in the trade could not afford to attend but had to enter immediately upon earning money, and further by the fact that the trade school could offer but few courses, thus lacking the variety of opportunity necessary to meet the needs.

A trade school for eight or nine trades is hopelessly inadequate for a community which needs workers trained in a hundred different lines. What we are trying to do in Milwaukee is to get vocational training on a learning-while-earning basis. Ours is a supplementary school, endeavoring to do in school the things that are usually neglected. We are trying to cover the different phases of trade, commerce, and industry, and with coöperation on the part of others we shall be able to cover the whole field adequately and comprehensively.

[1] Director of Vocational Education, Milwaukee, Wis.

Discussion of Papers on Apprenticeship

FRANK CUSHMAN[1] wrote that Milwaukee had one of the best programs of apprenticeship training for the metal trades to be found anywhere in the United States. Milwaukee also had one of the best and most efficient vocational schools in the country. The ordinary reader, however, might gather from a reading of Mr. Falk's paper that Milwaukee was the only point in the United States which had made very much headway in apprentice training. The casual reader would also infer that there was no widespread plan at present in operation in the United States for promoting apprenticeship training.

The need for vocational education, of which apprenticeship in the skilled trades was but one phase, had been generally recognized for a number of years. During the eight-year period prior to the passage of the National Vocational Education Act of 1917, vocational education in the industrial field had been a topic of major importance, and for a number of years bills had been introduced into Congress and hearings held before congressional committees for the purpose of devising ways and means of meeting the needs of the situation. A report of President Wilson's Commission on Vocational Education, made in 1914, set forth very clearly the reasons why apprenticeship and other forms of industrial education constituted a problem of national importance, and it was largely as a result of the work of this commission that Congress had enacted the law commonly known as the Smith-Hughes Act.

Under the provisions of this act, forty-eight state boards for vocational education had coöperated with the Federal Board for Vocational Education for nearly eight years. The problems involved in the development of the program had not been simple. Many persons, however, who had been in touch with the situation as it had existed in this country for the past ten years were of the opinion that the results achieved because of the stimulus supplied by the Smith-Hughes Act had far exceeded anything that was visualized by the President's Commission of 1914.

In view of the facts in the case it could fairly be claimed that not only was there a national organization actively at work in promoting apprenticeship and other forms of industrial education, but that important, valuable, and far-reaching results were being secured under the National Vocational Education Act. In 1917 only three or four of the states had developed trade schools. In 1924 approximately 410,000 persons were enrolled in publicly supported trade and industrial classes. Of this number more than 300,000 were

[1] Chief, Industrial Education Service Federal Board for Vocational Education, Washington, D. C.

persons who had left the regular schools and entered employment in industry. Of this latter number at least 10,000 were apprentices in the skilled trades, the remainder being either young workers who were attending part-time schools or persons employed in industry who were attending evening trade-extension classes.

As an indication of the scope of this work a recent survey of trade schools in the United States showed that during the year 1923–24 there were 1192 separate trade courses in operation in the United States which met the standards set up by the Federal and state boards. These courses were subdivided into 146 distinct courses of instruction dealing with more than 100 industrial occupations. The 146 distinct courses might be grouped into fourteen general classes of occupations for the purpose of illustrating the degree to which the public program of trade and industrial education was serving the needs of industrial workers. The number of employed workers enrolled in the public evening trade-extension classes was more than two and one-half times the number of boys and girls enrolled in the day and part-time classes covered by the survey. In the evening-school program a recent review of the situation showed that there was no major group of industrial occupations the workers in which had not been reached to a certain extent by the opportunities for education and training offered by the public schools.

The work was growing and being carried forward with an increasing degree of efficiency. Success in any given situation was possible through the coöperation of all the interested parties. The country would continue to look toward Milwaukee for new ideas as to better methods of handling industrial education in general and apprenticeship in particular, but many cities had already realized that they each had a local problem to solve and were proceeding to set up plans whereby they might train their own mechanics. There were, of course, important cities here and there that had done little or nothing toward establishing plans either for apprenticeship or for other forms of trade and industrial education. The number of such cities, however, was rapidly diminishing and in the very near future it would be possible to say that every American community was doing its share in providing not only opportunities for apprentices to get a thorough training but a real opportunity for all workers employed in the ordinary occupations of life to get such education and training as they needed to better equip them for their jobs and prepare them for advancement.

H. A. Frommelt[1] said that the objections ordinarily voiced regarding apprenticeship had absolutely no foundation. One objection, he said, was that the boys were going into higher education. However, figures published by the United States Bureau of Education showed that out of 100 children, only 67 were graduated from the eighth grade, 34 entered high school, 16 were graduated from high school, 7 entered college, and only 2 were graduated from college. Another objection was that the boys were going into "white collar" jobs. This tendency, he showed, was because of the manner in which they were received and treated when attempting to learn a trade by entering an industry; in other words, the boys were not running into the "white collar" jobs but were running from the conditions in the shops.

There were serious objections to apprenticeship as industry was organized, he said. Under the present system, a few of the large shops had to undertake the apprenticeship training for the entire community. Inasmuch as this was impossible, it became necessary, as in Milwaukee, to work out a coöperative system by grouping large and small shops so that each did its share in the training.

He was glad that Mr. Thomas had insisted that the cost of training apprentices should not be taken into consideration. While it was not possible to neglect this feature entirely, he said, it was impossible to figure it out in dollars and cents because the value of the training could not be measured in that way.

Luther D. Burlingame[2] spoke of the apprenticeship system founded more than one hundred years ago by Joseph R. Brown. At the end of his long and successful career, Mr. Brown had said that the apprenticeship system was the foundation upon which the business was built. It was true, he said, that most of the company officials and men in prominent positions had come up from the ranks, and that the apprenticeship system had kept pace with modern requirements. While the company had the handicap of specialized work, the system had been carried from department to department. The problem was to give the boy a knowledge of all departments, and not just a short time in each. The boy was interviewed by the officials of the company, he said, as to his ambitions and progress. Of this interview a record was kept and later checked up to see whether or not the boy was carrying out his ambitions.

E. E. Sheldon[1] said that after seventeen years of apprenticeship system, 80 per cent of the graduates were still with his company and 20 per cent were in executive positions. They had no trouble in getting apprentices at present, there being with them one from Connecticut, one from Georgia and one from Los Angeles, who had come because of the training in the printing industry which they would get. He expressed himself in favor of a national apprenticeship system.

E. H. Neff[2] called attention to a paper[3] presented twenty-five years ago by M. P. Higgins on the education of machinists, foremen, and mechanical engineers. He said that one of the unattractive features of the apprenticeship system was the fact that the apprentice did not receive enough money to keep him, so that he had to receive outside aid. Mr. Thomas had been wise in ignoring the expense on account of the results, and it was his belief that if manufacturers in general were more liberal there would be plenty of applicants for positions.

John J. Metz,[4] in commenting on Mr. Cushman's discussion, said that people in Milwaukee did not think theirs was the only apprenticeship system, nor were they ignorant of the work being done throughout the nation. The problem was that of the small shop, and the Milwaukee solution was thought to be unique. He felt that the idea of grouping a number of small shops together and interesting them in training a boy so that he might be graduated, after going through all the shops, as a competent mechanic, was applicable to all parts of the country.

Charles R. Gabriel[5] spoke of the failure of the apprenticeship system at the E. W. Bliss Company and of its adverse reaction on the supply of good mechanics. It was difficult, he said, to interest boys in New York in apprenticeship courses because of the low rates of pay. He asked if some way could be devised making it possible to pay a boy a living wage during his apprenticeship course.

Erik Oberg[6] said that he had investigated a number of apprenticeship systems and had found one in the machine-tool industry in which boys were paid from fifteen to twenty-five dollars a week for a period of four years. The apprentice force amounted to about 15 to 25 per cent of the entire force, depending on whether business was good or poor, but it was the backbone of the organization. The investment made in the boy was considered a good one. The three- and four-year apprentice boys were the main skilled force. In forty years' time every mechanical position would be filled by a past apprentice.

C. J. Freund[7] said, regarding compensation, that he had been able to get boys on the educational value of the training. More than 60 per cent of apprentices, he said, had been engaged before ever bringing up the question of compensation.

In his closure to the discussion, Mr. Falk said that Milwaukee had not intended to claim credit for being the only practicers or the originators of apprenticeship systems. Their endeavor had been entirely in the metal industries, and their hope was to promote a national program in the metal trades.

Mr. Thomas made some comparisons of compensation in the trades and in the professions.

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[1] Supervisor of Training Dept., The Lakeside Press, R. R. Donnelley & Sons Co., Chicago, Ill.

[2] New York Manager, Brown & Sharpe Mfg. Co., New York, N. Y. Mem. A.S.M.E.

[3] Trans., A.S.M.E., vol. 21 (1900), p. 646.

[4] District Supervisor of Apprentices, Milwaukee Vocational School, Milwaukee, Wis.

[5] Consulting and Designing Engineer, E. W. Bliss Co., Brooklyn, N. Y. Mem. A.S.M.E.

[6] Editor, *Machinery*, New York, N. Y. Mem. A.S.M.E.

[7] Apprentice Superintendent, Falk Corporation, Milwaukee, Wis. Jun. A.S.M.E.

Radiation in the Pulverized-Fuel Furnace

By WALTER J. WOHLENBERG,[1] and DONALD G. MORROW,[2] NEW HAVEN, CONN.

This paper deals with the fundamentals concerning radiation in the pulverized-fuel furnace. It is shown that the radiating power through the flame surface depends primarily on the size of the particle, and that, based on the flame-surface area, its magnitude relative to black radiation is low. The heat-absorption intensity at the cold surface, however, may be considerably higher than the relative radiance of the flame. This factor depends on both the amount and the disposition of the refractory furnace lining. Application of the method outlined enables, by an analytical process, quantitative evaluation of the furnace energy process, and the data yielded are of such a nature as to indicate by comparison which furnace proportions will give the best results.

IN THIS paper an attempt is made to solve by analytical methods the energy process occurring in the boiler furnace. The general theory is applicable to any boiler furnace, but special devices have been included for its particular application to the pulverized-fuel furnace.

Type of Results Obtainable

Some of the significant results yielded by the application of such a theory may be enumerated as follows:

a Radiating mean value of the flame temperature, T_V.

b Radiating mean value of the refractory temperature, T_R.

c Radiation intensity of the flame surface compared to that of a black body. This is called the relative radiance, μ_1.

d The radiation efficiency of the furnace compared to that furnace in which the cold surface is immediately in front of a perfectly black fuel bed at the temperature T_V, designated by the symbol μ_2. It is a measure of the radiant and reflected energy which actually strikes the cold surface as compared to that which would strike it with a perfectly black fuel bed immediately in front of it. It does not include the heat absorption by convection at the cold surface and does not correct for the reflection from the cold surface.

e The total heat absorption at the cold surface compared to that which would result by means of radiation only in a furnace with a black fuel bed immediately in front of the black tubes. This quantity is called the relative absorption, and is represented by the symbol μ_3.

f The fraction of liberated energy which is absorbed in the furnace. This quantity is called the furnace absorption efficiency and is designated by the symbol μ_4.

g The influence of furnace volume, shape, and disposition of cold surface on the foregoing quantities.

h The influence of rates of energy liberation on the foregoing quantities for a given furnace.

i The influence of fineness of pulverization on certain of the foregoing quantities.

The cold- and refractory-surface arrangements for the cubical furnace considered are designated as follows:

Arrangement A. Cold surface at the top face only, which forms the aperture for the escaping gases.

Arrangement B. Cold surface at the top and bottom faces, the aperture for the escaping gases being at the top.

Arrangement C. One-half of the interior surface as cold surface, distributed so that one-half of the top, bottom, and two sides, and total furnace back is cold surface.

Arrangement D. Top, bottom, and two opposite sides as cold surface.

Arrangement E. Furnace totally enclosed by cold surface.

Some of the data for the various surface arrangements at different rates of energy liberation are represented graphically in Figs. 1, 2, 3, 4, and 5.

Discussion of Results

Comparison of Furnace Types. Comparing furnace *B* with furnace *C*, it is to be noted that *C* contains considerably more cold surface than *B* but that the flame temperature of *C* is only slightly lower, and, contrary to expectations, the refractory temperature of *C* is actually higher than that of *B*. The result is only a slightly greater heat absorption (compare values of μ_4) by *C* for a considerably increased cold surface. This condition exists because in *C* the cold surface "sees" other cold surface through a much greater solid angle than it does in *B*. Likewise the refractory "sees" other refractory through a larger solid angle. The net heat absorbed from the refractory radiation and reflections by the cold surface is thus considerably less in *B* in spite of the increased cold surface. The disposition of the cold surface and the furnace shape thus have a marked influence on its effectiveness for absorbing heat radiations from the refractory.

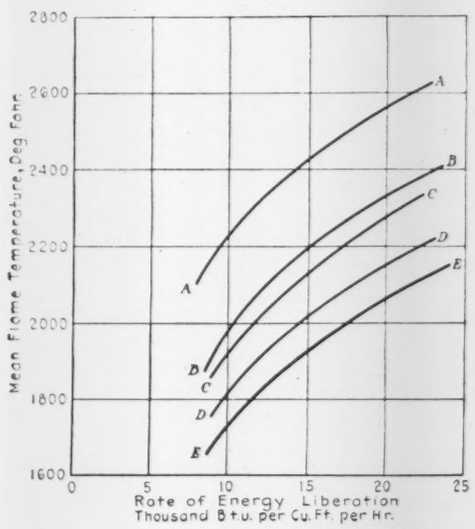

Fig. 1 Variation of Mean Flame Temperature with Rate of Energy Liberation

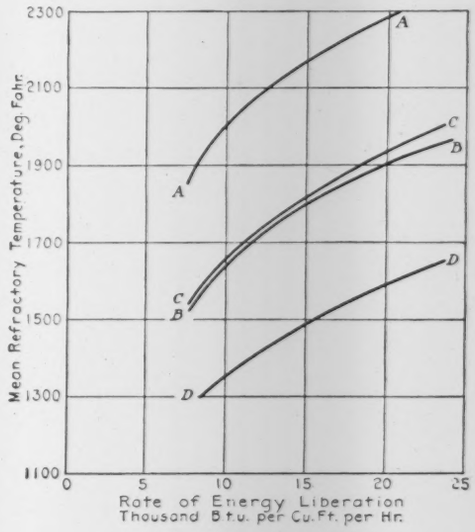

Fig. 2 Variation of Mean Refractory Temperature with Rate of Energy Liberation

Influence of Energy-Liberation Rate. Fig. 3 shows that, although the coefficients μ_1, μ_2, and μ_3 do not change greatly, the fraction of liberated energy μ_4, which is absorbed in the furnace, decreases rapidly with increase of energy liberation. This means that a larger part of the liberated energy must be absorbed in the convection zone of the boiler and hence that the efficiency must necessarily decrease, which is otherwise obvious by inspection of the flame-temperature curves, Figs. 1 and 2.

Other Black-Body Comparisons. Of particular importance is the disclosure that the relative radiance μ_1 of the flame cannot, for

[1] Associate-Professor of Mechanical Engineering, Yale University. Assoc-Mem. A.S.M.E.

[2] Yale University.

Acknowledgment. The authors wish to express their indebtedness to Mr. A. B. Stickney, II, a graduate student at Yale, for suggesting a number of valuable devices which have been a great service in working out this problem.

Contributed by the Fuels Division and presented at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of The American Society of Mechanical Engineers. Abridged, and with the sample calculations and appendices of the original paper omitted.

average conditions, be equal to that of a black body. This condition is reflected also in reduced values of the radiating and absorption efficiencies. Calculations based on black-body assumptions thus result in an error whose magnitude is high or low, depending upon the fraction of the envelope which is composed of refractory surface. For a large fraction of refractory surface the re-radiated and reflected energy adds to the direct radiations discharged from the flame to the cold surface, but even here it appears that an error of 20 to 30 per cent is easily possible.

Influence of Pulverization Fineness and Flame Volume on Relative Radiance. Figs. 4 and 5 illustrate the variation of the relative radiance with flame and particle size. For the average particle size as determined when 75 per cent of the sample is passed through a 200-mesh screen, the variation of relative radiance is not large until the flame becomes comparatively small. It should be noted that the radiance improves appreciably as the particle is reduced in size.

For very large particles the radiance of course is materially reduced because of the now decreased surface area on the relatively few particles in suspension, and eventually the influence of particles becomes small even as compared to the radiating portions of the gaseous constituents.

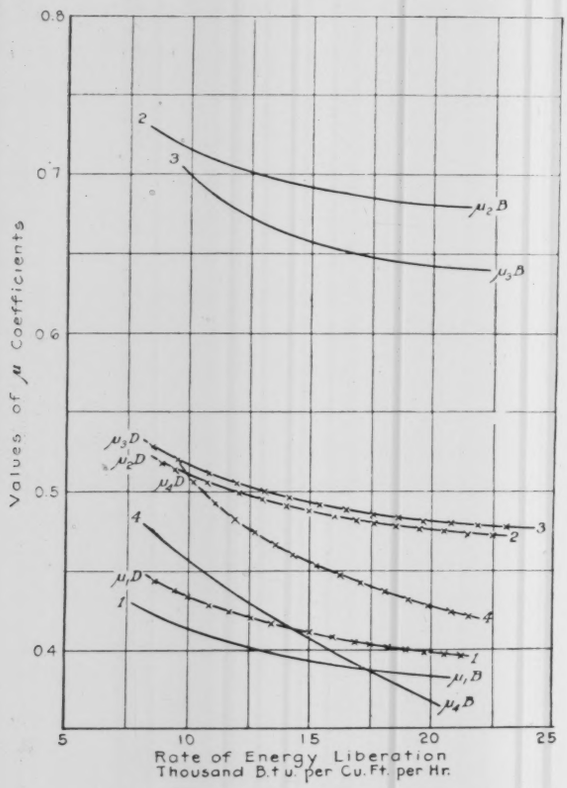

FIG. 3 COMPARISON OF μ_1, μ_2, μ_3, AND μ_4, CASES *B* AND *D*

UTILITY OF RESULTS

Perhaps the most useful data, if correct, yielded by such an investigation are contained in the values of the coefficients μ_1, μ_2, μ_3, and μ_4. It is obvious that their magnitudes are indicative of the effectiveness of both the flame and furnace as a partial means of transferring liberated energy to the water and steam. The relative radiation values of various furnace types and surface arrangements apparently can be evaluated with reasonable accuracy in such terms, even if the various temperature magnitudes arrived at do not describe in sufficient detail the actual flame as to temperature dimensions. These coefficients are therefore of use to the designer of heat-absorbing vessels in evaluating the convection zone, as well as in evaluating the furnace conditions.

GENERAL METHOD

The energy equation of the boiler furnace may be stated in the form:

$$dQ_U/dt = dQ_B/dt + dQ_F/dt \quad [1]$$

The first term, dQ_U/dt, represents the time rate of energy liberation by burning fuel in the furnace. Its magnitude in B.t.u. per hr. is expressed by the product

$$G_U U \quad [2]$$

in which U represents the B.t.u. actually liberated per pound of fuel fired and G_U the pounds of fuel fired per hour. If the fuel is completely burned, U represents its calorific value.

The second term, dQ_B/dt, represents the rate at which *liberated energy* is absorbed by the *burned gases* in raising the temperature from initial conditions to the flame temperature. Its magnitude is the result of heat addition at constant pressure to each of the constituents forming as a whole the burned-gas mixture. Symbolically this quantity may be expressed in the form

$$G_{CO_2}\Delta h_{CO_2} + G_N \Delta h_N + G_O \Delta h_O + G_{SO_2}\Delta h_{SO_2} + \ldots \quad [3]$$

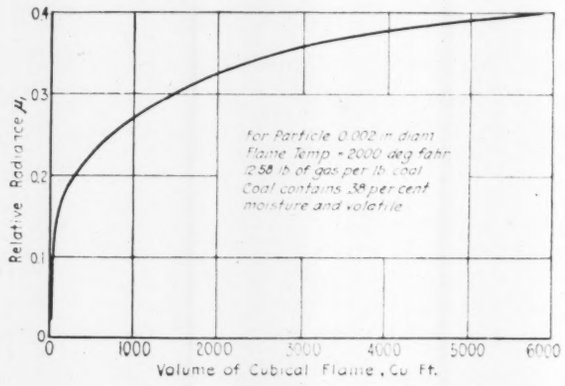
Relative Radiance μi
Volume of Cubical Flame, Cu. Ft.
for Particle 0.002 in diam
Flame Temp = 2000 deg fahr
12.58 lb of gas per lb coal
Coal contains 38 per cent
moisture and volatile

FIG. 4 VARIATION OF RELATIVE RADIANCE WITH FLAME SIZE

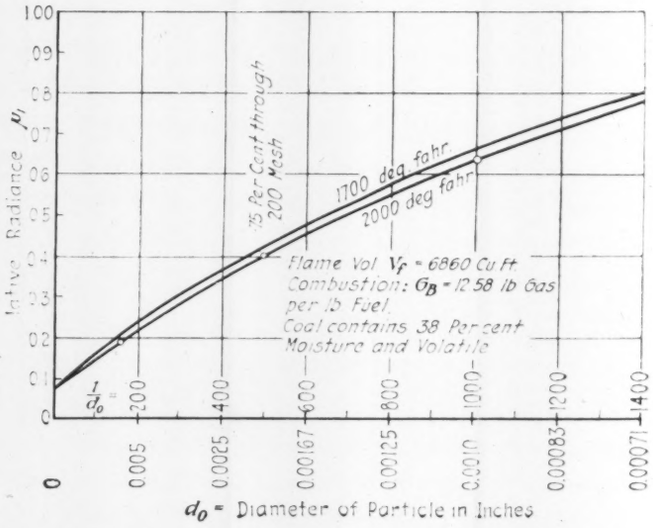
Relative Radiance μi
75 Per Cent through 200 Mesh
1700 deg fahr
2000 deg fahr
Flame Vol Vf = 6860 Cu Ft
Combustion: GB = 12.58 lb Gas per lb Fuel
Coal contains 38 Per cent Moisture and Volatile
do = Diameter of Particle in Inches

FIG. 5 VARIATION OF RELATIVE RADIANCE WITH FLAME-PARTICLE SIZE

in which G_{CO_2}, G_N, G_O, etc., represent the weights, lb. per hr., of the constituents CO_2, N_2, O_2, etc., and the multiplying terms Δh_{CO_2}, Δh_N, etc., the heat capacities at constant pressure between the initial temperature T_1 and the flame temperature T_U. The sum of the products $G\Delta h$ then yields quite accurately the energy absorption rate dQ_B/dt by the burned gases.

The last term, dQ_F/dt, represents the time rate of energy loss from the solid and gaseous portions of the flame during their travel through the furnace. This term has the general dimensions

$$dQ_F/dt = K(T_U^n - T_c^n) + Z \quad [4]$$

in which K is a constant, T_U the absolute mean radiating temperature of the hot body, and T_c the absolute mean radiating temperature of the cold body. With $n = 4$, the term $K(T_U^4 - T_c^4)$ represents the Stefan-Boltzmann law, in which form it is applicable within the limits of error involved in the definition of other conditions. The term Z denotes the heat transferred by convection

as the gases flow along the furnace walls. It may be otherwise represented as

$$Z = \Sigma S z \Delta t \quad [5]$$

in which S represents furnace-wall surface, z the coefficient of heat transfer in B.t.u. per hr., and Δt the mean temperature difference between the furnace wall and the layer of moving gas immediately in front of the surface. The constant K depends on a great many factors and its evaluation presents one of the chief problems of this paper.

Both the solid fuel portions and the gaseous flame masses radiate to both the refractory and exposed boiler surfaces. The transfer of heat by convection occurs also at all of the walls to a greater or less extent, and the process is further complicated by reflection from the various surfaces. Fig. 6 is a graphical representation of such an activity resolved into those net effects in terms of which the general equations may be stated.

The total energy as heat supplied to the furnace is thus divided into four parts, such that

$$Q_I = Q_U + Q_{AR} + q_{CR} + q_{CT} \quad [6]$$

in which Q_U = energy liberated by burning the fuel

Q_{AR} = energy transferred from the furnace walls to the air supplied for combustion

q_{CR} = that part of the radiated energy $(Q_{RC} + q_{RC})$ discharged from the refractory R which strikes the cold surface C and is reflected back into the furnace, and

q_{CT} = that part of the energy Q_{TC} discharged from the flame mass which by direct radiation strikes the cold surface and is there reflected back into the furnace.

The net heat loss Q_F from the flame mass is thus a sum of the quantities

$$X_R + Q_{CR} + Q_{CT} + Z_C \quad [7]$$

in which X_R has been defined, and Q_{CR} and Q_{CT} denote respectively the heat absorptions at the cold surface by virtue of radiations and reflections from the refractory to the cold surface, and radiations from the flame and fuel mass to the cold surface. The last term Z_C indicates the energy absorbed by convection at the sum total of the exposed cold surface in the furnace which is not located at the aperture through which the gases escape into the principal convection zone of the boiler. Heat absorbed by convection at the point of escape for the gases can obviously have little or no influence on the furnace-flame temperature as a whole, even though it does reduce the gas temperature at the gas-discharging furnace boundary.

General Furnace Heat-Flow Equations

The time rate of energy loss from the flame, as shown by Equation [7], may be expressed in the form

$$dQ_F/dt = X_R + Q_{CR} + Q_{CT} + Z_C \quad [8]$$

in which

$$Q_{CR} = (Q_{TR} + Z_R - Q_{AR} - X_R)(1 - \beta_{CN}) \quad [9]$$

and

$$Q_{CT} = Q_{TC}\,(1 - \beta_{CN}) \quad [10]$$

in which β_{CN} denotes the coefficient of reflection at the cold surface. Investigation shows that with an increase in furnace air temperature of 100 degrees Q_{AR} represents approximately two per cent of the liberated energy. The heat Z_R transferred by *convection only*[1] to the interior refractory surface is likewise in the vicinity of one to three per cent of this energy. It follows that within the limits of error involved, Z_R may be taken equal to Q_{AR}. With this assumption, Equation [8] may be expressed in the form

$$dQ_F/dt = (Q_{TR} + Q_{TC})(1 - \beta_{CN}) + Z_C \quad [11]$$

Since both the gaseous and solid fuel masses radiate, the above equation is now stated in the form

$$dQ_F/dt = (1 - \beta_{CN})[(K_1' + K_1'')(T_U^4 - T_R^4) + (K_2' + K_2'')(T_U^4 - T_C^4)] + Z_C \quad [12]$$

[1] Differentiating between the heat transferred from the gases to the refractory by radiation and by convection.

in which the first product within the square brackets represents Q_{TR} and the second product Q_{TC}. Of the constants, K_1'' has such a value that the product $K_1''(T_U^4 - T_R^4)$ represents the energy radiated to the refractory from the radiating gaseous portions, and K_1' the corresponding value applicable between the solid fuel portions and refractory. The constants K_2' and K_2'' represent similar coefficients, applicable respectively between burned gaseous and solid fuel portions and the exposed boiler surfaces. Before Equation [12] may be solved the relation between the mean radiating refractory temperature T_R and the temperatures T_U and T_C obviously must be established.

An additional equation is furnished by the fact that the heat radiated from the refractory added to the heat loss through the refractory by conduction must be equal to the heat absorbed by the refractory when the equilibrium state is reached as to the temperature T_R. In terms of the nomenclature of Fig. 6, this is expressed algebraically as

$$Q_{TR} + Z_R - Q_{AR} - X_R - q_{RC} = Q_{RC}$$

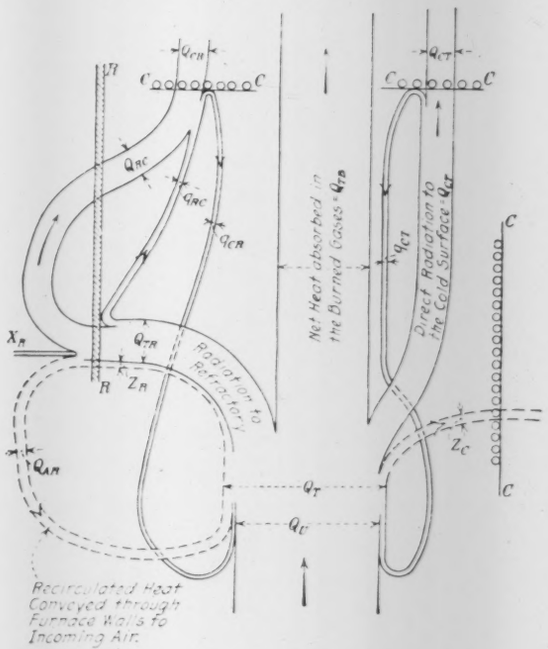
Net Heat absorbed in the Burned Gases = Q_{TR}
Direct Radiation to the Cold Surface = Q_{CT}
Radiation to Refractory
Recirculated Heat Conveyed through Furnace Walls to Incoming Air

FIG. 6 FURNACE ENERGY DIAGRAM

As before, Z_R, Q_{AR}, and X_R are very small quantities, whence the difference

$$Z_R - (Q_{AR} + X_R)$$

may be taken as zero, and

$$(Q_{TR} - q_{RC}) = Q_{RC}$$

But q_{RC} is the net reflection from the refractory to the cold surface, whence the above equation is expressible as

$$Q_{TR}(1 - \beta_{RN}) = Q_{RC} \quad [13]$$

in which $(1 - \beta_{RN})$ represents the net reflection coefficient from refractory to cold surface. In terms of the temperatures involved, this equation is then stated in the form

$$K_1(T_U^4 - T_R^4)(1 - \beta_{RN}) = K_3(T_R^4 - T_C^4) \quad [14]$$

in which $K_1 = (K_1' + K_1'')$, and K_3 is a similar coefficient applicable between the refractory and cold surface. Solving [14],

$$T_R^4 = \frac{(1 - \beta_{RN})K_1 T_U^4 + K_3 T_C^4}{(1 - \beta_{RN})K_1 + K_3} \quad [15]$$

Placing $K_2' + K_2'' = K_2$, and substituting [15] in [12], the resulting equation is

$$dQ_F/dt = (1 - \beta_{CN})\left[\frac{K_1 K_3}{(1 - \beta_{RN})K_1 + K_3} + K_2\right][T_U^4 - T_C^4] + Z_C \quad [16]$$

This equation represents the furnace energy loss from flame and solid fuel portions. It differs from the heat absorption ($Q_{CR} + Q_{CT} + Z_C$) at the exposed boiler surfaces by the quantity ($X_R + Q_{AR}$), whence the heat absorption at the exposed surface is equal to

$$dQ_A/dt = dQ_F/dt - (X_R + Q_{AR}) \quad [17]$$

By substituting from [2], [3], and [16] in [1], the equilibrium equation is stated in the final form

$$G_U U = \Sigma G_B \Delta h_B + (1 - \beta_{CN}) \left[\frac{K_1 K_3}{(1 - \beta_{RN})K_1 + K_3} + K_2 \right] [T_U^4 - T_C^4] + Z_C \quad [18]$$

For a given temperature T_C the magnitude of heat capacities Δh_B, as well as that of some of the constants K, depends, as will later be shown, on the temperature T_U. The solution for T_U is necessarily the result of a series of trials. The method is one of assuming a trial value of T_U and for this evaluating all of the quantities dependent on it. Such values are substituted in [18], which is then solved for T_U. When the latter value agrees with the trial value on which the various magnitudes are based, the solution is correct in all details for the assumed furnace conditions. Before attempting a more exact definition of the various constants involved, it is now advantageous to examine the physical process in more detail.

Physical Nature of the Process

A particle such as a, Fig. 7, radiates both above and below the plane $p-p$. For convenience the particles may be assumed to be small spheres, each of which has the same volume as that of the mean particle, whence the total radiation through a hemisphere (solid angle = 2π) is that from one-half the total spherical surface. Similarly the radiation to any point from the particle is the sum total of radiations to that point from all surface points which can "see" the receiving point. Any point can thus "be seen" by one-half of the surface of the particle.

Radiations from the particle are discharged in all directions. Some will strike the refractory R at points as b, others will strike the cold surface C, at points such as C''. A part of the radiations striking at b are *reflected* as shown by the ray $b-c$. This *reflected* ray is largely absorbed at c, whence only a small portion is finally reflected to the cold surface at d and a still smaller portion of the already reduced ray $d-c$ is reflected from the cold surface back into the furnace.

The reflective coefficients in practical furnaces are low, whence the refractory walls absorb heat and assume a temperature T_R between that of the radiating body and the cold surface. Since T_R is greater than T_C, any point e of the refractory surface will radiate net energy to the cold surface. Radiation will also occur between the hotter and colder portions of the refractory.

Practically all of the radiated and reflected rays pass through the flame masses. A radiating surface thus "sees" the surface to which it is radiating as through a cloud. This cloud interferes with the ray unless the particles of the cloud are perfect reflectors, when the vision would be, as before mentioned, as though unobstructed. This flame or cloud interference is caused principally by the solid particles in suspension, but the CO_2 and H_2O molecules[1] likewise absorb an appreciable amount of the radiant energy which strikes them.

To study the reflection in more detail, consider a particle such as o in the furnace of Fig. 8. The rays, a, b and c are reflected respectively one, two, and three times before striking the cold surface. All rays striking between a and b are thus reflected once, whereas those between b and c, and c and o are reflected respectively two and three or more times. The fraction of the energy radiated to the refractory which eventually is impinged on the boiler surfaces by the paths of reflection may thus be approximated by application of a weighted average such as

$$\beta_{NR} = \frac{\Delta a \beta_R + \Delta b \beta_R^2 + \Delta c \beta_R^3 + \ldots . {}^1/_2 \Delta n \beta^n}{\Delta a + \Delta b + \Delta c + \ldots . {}^1/_2 \Delta n} \quad [19]$$

[1] Wien, Julius, and others have shown that these are the only gaseous molecules which absorb and radiate appreciable amounts of heat.

It is also apparent that the furnace shape and refractory distribution have some influence on the actual magnitude of β_{NR}. The fraction of total striking rays which are reflected only once is obviously seldom over one-third of the total striking rays, whence $\Delta\beta_{NR}$ will practically always be considerably less than the reflection coefficient β_R at a point of the refractory surface. If we may assume the angles $\Delta a = \Delta b = \Delta c$, $\Delta\beta_{NR}$ is very nearly ${}^1/_2\beta_R$, which value may be used as an approximation. The net reflection β_{NC} from the cold surface back into the flame is obviously equal to β_C, the coefficient of reflection of that surface when the surface is considered as one or more flat plates. For tubular surface as shown at the bottom of Fig. 8, approximately one-half of the reflections would be directed deeper into the boiler, thus resulting in $\beta_{NC} = {}^1/_2\beta_C$.

Constants Applicable between Solids and Solids for Radiation through the Flame Cloud

The radiation constant K_1' applicable between a solid particle in the flame and a refractory surface is now stated in the form

$$K_1' = \alpha'_U I_g (1 - I_S) \frac{S'_U}{2} \times \frac{\omega'_{UR}}{2\pi} \quad [20]$$

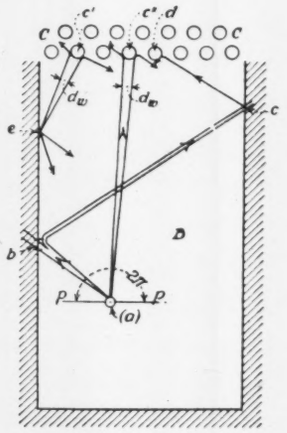

FIG. 7 RADIATION FROM A PARTICLE

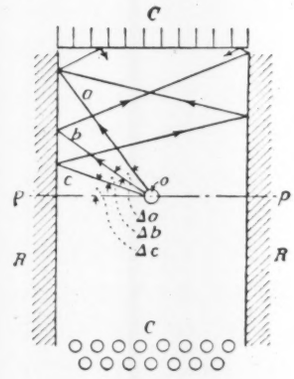

FIG. 8 STUDY OF REFLECTION

in which

α'_U = radiation coefficient at the fuel surface when radiating through a perfect reflecting or unclouded medium

I_g = radiation penetration coefficient through the gaseous media

I_S = mean shielding coefficient of solid particles for each other

ω'_{UR} = mean solid angle subtended by the receiving from the radiating surface, and

S'_U = total surface area of particles in suspension at any instant, sq. ft.

Similarly

$$K_2' = \alpha'_U I_g (1 - I_S) \frac{S'_U}{2} \times \frac{\omega'_{UC}}{2\pi} \quad [21]$$

in which ω'_{UC} represents the mean solid angle subtended by the cold surface from the radiating particles.

The refractory surfaces act as an extended solid fuel bed in radiating energy to all parts of the furnace. The net discharge is that through the solid angle subtended by the cold surface from the refractory. The form in which K_3 is expressed depends upon the place at which this discharged energy is to be analytically measured. Thus it is definable in terms of the discharge from the refractory wall toward the cold surface and also in terms of energy received at the cold surface by the discharge from the refractory wall. In terms of the first definition we have

$$K_3 = \alpha_{RI} I_g (1 - I_S) \frac{\omega_{RC}}{2\pi} S_R \quad [22]$$

and in terms the second definition

$$K_3 = \alpha_{RI} I_g (1 - I_S) \frac{\omega_{CR}}{2\pi} S_C \quad [23]$$

RADIATION INTENSITY FROM GASEOUS MASSES

The net radiation exchange between a gaseous flame and a colder solid body is, as shown by Julius,[1] largely due to the CO_2 and H_2O molecules. Professor Tyndall[2] has shown that these products of combustion likewise absorb heat, which of course they should if they act as radiators. All other molecules in the gaseous mixture apparently act as nearly perfect reflectors.

Callendar found that the "intrinsic radiance" for a given kind of molecule depnds on the density and thickness of the radiating gaseous column, but that when the flame depth is two feet or over in thickness, increased depth ceases to influence the radiation intensity per unit area of flame surface. From his experiments it thus appears reasonable to use a value of $\alpha''_U = 0.07\alpha_0$ for the radiation intensity at the flame surface. That is,

$$\alpha''_U = 0.07 \times 1.62 \times 10^{-9} = 1.135 \times 10^{-10} \quad [24]$$

Since the radiation from the gaseous masses may be based wholly on their outside surfaces, the radiation constants K_1'' and K_2'' may be expressed within the limits of accuracy of other data by the relations

$$K_1'' = \alpha''_U \frac{\omega''_{UR}}{2\pi} S''_{UR} \quad [25]$$

$$K_2'' = \alpha''_U \frac{\omega''_{UC}}{2\pi} S''_{UC} \quad [25a]$$

in which

S''_{UR} = flame surface which can "see" the refractory
S''_{UC} = flame surface which can "see" the cold surface
ω''_{UR} = mean solid angle subtended by refractory from flame surface which can "see" the refractory
ω''_{UC} = mean solid angle subtended by cold surface from flame surface which can "see" the cold surface.

THE COEFFICIENTS α', I_g, I_S, AND OTHER QUANTITIES[3]

The radiation coefficient α' is obtainable from the relation

$$\alpha' = (1 - \beta)\alpha_0 \quad [26]$$

in which β represents the reflection coefficient at the surface in question and α_0 the black-body radiation coefficient. α_0 is equal to 1.62×10^{-9} and β has the following approximate magnitudes:

Well-sooted metal surface, 0.05
Clean boiler tubes, unpolished, 0.10
Ordinary clean refractory, 0.10
Well-sooted refractory, 0.05.

The penetration coefficient I_g for radiations through the gaseous media may be approximated from the relation

$$I_g = \frac{\alpha_0 - \alpha'}{\alpha_0} \quad [27]$$

The value of the mean shielding coefficient I_S is obtainable from the relation

$$I_S = 87.1 \frac{V_f^{1/3} K_0^2}{G_B T_U \delta_0 d_0} - 64.2 \times 10^2 \left[\frac{V_f^{1/3} K_0^2}{G_B T_U \delta_0 d_0}\right]^2 \quad [28]$$

in which

V_f = flame volume in cubic feet
G_B = pounds of burned gas per pound of fuel
T_U = mean radiating flame temperature, deg. fahr.
d_0 = initial mean diameter of the fuel particles
K_0 = coefficient such that $K_0 d_0$ is equal to the mean particle diameter with moisture and volatile expelled
δ_0 = weight of fuel per cubic foot.

The total number N_t and area S'_U of particles in suspension is obtainable from the following relations:

$$N_t = 130.6 \times 10^3 \frac{V_f}{G_B T_U \delta_0 d_0^3} \quad [29]$$

$$S'_U = 950 \frac{V_f K_0^2}{G_B T_U \delta_0 d_0} \text{ (sq. ft.)} \quad [30]$$

BLACK-BODY COMPARISONS AND FURNACE ABSORPTION EFFICIENCY

When a solution has been obtained which satisfies Equation [18], the results may be compared to the black-body intensities of the same temperatures. Such data are particularly valuable when quick approximations of radiating conditions are to be attempted. In this respect the relative analytical measurements may advantageously be made in three ways.

For the first comparison the intensity of total radiation from the flame surface is compared to that of a black body having the same volume, surface, and temperature. The measurement is conveniently taken by considering the flame in question as completely enclosed by the cold surface C. The solid angles ω'_{UC} and ω''_{UC} now become equal to 4π. Since no refractory surface is now present, the surface S_R is obviously equal to zero. The ratio[1] of actual total radiation to that of the black-body flame is then expressed as

$$\frac{\alpha'_U I_g (1 - I_S) S'_U + \alpha''_U S''_{UC}}{\alpha_0 S''_{UC}} = \mu_1 \quad [31]$$

The factor μ_1 is thus the relative radiance of the flame.

For the second comparison the furnace as a whole is compared to one in which the fuel surface is considered directly in front of the cold surface and equal to the latter in extent. For this condition the ratio[1]

$$\frac{\dfrac{K_1 K_3}{(1 - \beta_{RN})K_1 + K_3} + K_2}{\alpha_0 S_{UC}} = \mu_2 \quad [32]$$

yields a value whose magnitude measures the energy striking the cold surface by paths of radiation and net reflection as compared to that striking the cold surface by radiation from a black fuel bed immediately in front of it. It is really the radiating efficiency of the furnace as a whole.

A third comparison results from the ratio[2]

$$\frac{dQ_A/dt}{\alpha_0 S_{UC}(T_U^4 - T_C^4)} = \mu_3 \quad [33]$$

This ratio measures the total heat absorption at the cold surface as compared to that striking this surface by the black fuel bed immediately in front of it. The quantity μ_3 is thus the relative absorption of the furnace as compared to that of a total black furnace with the same amount of cold surface.

The fourth coefficient μ_4 represents the furnace absorption efficiency and is equal to the relation between the energy liberated and that absorbed by the exposed cold surface. This, however, does *not* include that absorbed as the result of convection by that cold surface at the aperture for discharging the gases into the convection zone of the heat-absorbing vessel. It does include that absorbed by convection at other exposed cold surface. This quantity is evaluated from the relation[3]

$$\mu_4 = \frac{dQ_A/dt}{dQ_U/dt} \quad [34]$$

INFLUENCE OF PULVERIZATION FINENESS, FLAME VOLUME, ETC.

By application of Equation [31] with proper use of the expression [28] for the shielding coefficient, the variation of flame radiance with such conditions as volume V_f, combustion efficiency G_B, size of particle d_0, and temperature T_U may be ascertained. Some such results have been shown in the curves of Figs. 4 and 5 and need not be further discussed at this time.

The foregoing analysis shows that in modern furnaces it is the congestion of particles of the sizes used, rather than the small size of the particle, which is a partial influence in causing the resulting temperature gradient.

OXYGEN INTENSITY

In discussing this condition it is convenient to introduce the

[1] Die Licht und Warmstrahlung verbrannter Gase.
[2] Preston, Theory of Heat.
[3] The development of Equations [27], [28], [29], and [30] is given in appendices forming a part of the complete paper, and limitations to the applicability of Equation [28] are also discussed there.

[1] Developed in an appendix to the original paper.
[2] See Equation [17].
[3] See Equations [17] and [2].

factor called "oxygen intensity." For solid fuels it is, as defined, exactly the pounds of oxygen colliding per hour (and hence burning) per unit fuel-surface area. For gaseous fuels it is the pounds of oxygen per hour per cubic foot of gaseous mixture. If, then, u_0 represents the energy liberated per pound of oxygen uniting with the fuel in question, the products

$$u_0\zeta_s S'_v = K'_v \quad \ldots\ldots [35]$$

$$u_0\zeta_v V_f = K''_v \quad \ldots\ldots [36]$$

yield the total rates of energy liberation in B.t.u. per hour, in which

ζ_s = surface oxygen intensity, solid fuels

and

ζ_v = volume oxygen intensity, gaseous fuels.

The oxygen intensities ζ_s and ζ_v should not be confused with the rapidity of this process once a uniform mixture is established. They are a measure of the speed of mixing.

Without going into details, it may now be said investigation shows, even when high-volatile coals are burned in the pulverized-fuel furnace, that the *required volume oxygen intensity ζ_v is far below that actually realized in the gas furnaces.* The burning of the volatile matter should therefore not at the present time limit the energy-liberation rate in pulverized-fuel furnaces.

We are concerned chiefly with the probable oxygen intensity at the surface of the fixed-carbon particles. Air is blown with a velocity λ toward the fuel sphere whose diameter is d. If the cross-sectional area of the stream is one square foot, the maximum volume in cubic feet per hour colliding is represented by the product 60λ, in which λ is the velocity in feet per minute. Then

$$\zeta_{s(\max.)} = \frac{60\lambda}{4.32RT_v/p} = 548\lambda/T_v \quad \ldots\ldots [37]$$

For an energy-liberation rate of 20,000 B.t.u. per cu. ft. per hr., which is near the limit with the most common methods of burning pulverized coal in boiler furnaces, the required ζ_s, with an initial mean particle size of 0.002 in. diameter, is approximately 10. It follows that the limiting mean relative velocity between the particles and the flame cannot be very much greater than 1 to 2 ft. per sec.

As the particles are decreased in size, the ratio of surface to weight per particle increases, whence the tendency will obviously be to reduce still further the relative velocities, and hence oxygen intensities, unless some other than the usual methods of creating turbulence can be found which is commercially satisfactory. If two flames should be directed one toward the other, the relative velocities would obviously be tremendously increased. Burners with perhaps a centrifugal discharging jet of high velocity may, when properly designed, offer a solution. With the present systems, however, it becomes apparent that finer pulverization *will probably not increase the rate* of energy liberation, because as the particle surface is increased the oxygen intensity ζ_s will probably decrease.

For modern furnaces then the curves of Figs. 4 and 5 are apparently as accurately representative as it is possible to predict.

Boiler Furnaces for Pulverized Coal

BY A. G. CHRISTIE,[1] BALTIMORE, MD.

An analysis of the fundamentals of the combustion of pulverized coal and of the effect of radiant heat and flame on the performance of boiler furnaces is presented in this paper. This analysis indicates that the following conditions are desirable for the highest efficiency and maximum capacity of a given furnace: Coal should be finely ground, thoroughly dry, and preheated before entering the furnace. Primary and secondary air should be highly preheated. Turbulence should exist inside the furnace. The walls should be water-cooled. New methods of handling ash and preventing the discharge of dust into the air should be developed. These will lead toward greater capacity for a given furnace volume and to higher boiler efficiencies.

THIS paper will consider some fundamental principles in connection with the combustion of pulverized coal and will note how these may be applied in the design of suitable furnaces. Certain methods of preparing, drying and firing coal and of handling ash will also be briefly discussed.

METHODS OF HEAT TRANSFER

A clear conception of the methods of heat transfer is necessary for an understanding of furnace problems. There are three methods of transfer, viz., conduction, convection, and radiation.

Conduction is the intermolecular transfer of heat within a body. For instance, one end of a copper bar is placed in a flame. This causes a large increase of molecular activity which is known as "increase in temperature." The vibrations of adjacent molecules increase and in this way the activity proceeds from molecule to molecule along the bar toward the cold end. If one end is kept cold, heat will continue to flow from the hot to the cold end. This physical phenomenon is called "conduction." Heat is transmitted through the metal walls of boiler tubes in this manner.

Convection refers to the mass transfer of heat. For instance, a certain volume of gas is heated by contact with a hot surface or by combustion, and rises due to decreased density or draft. Later the gas comes in contact with a cold body, to which it gives up its heat. A greater part of the heat is delivered by flue gases to the second and third passes of a boiler, to economizers, and to air preheaters by means of convection.

Radiant energy is a form of activity in the ether similar to light and electricity. Heat radiations are wave actions and differ from light and electricity only in wave length. The molecules of a hot body are assumed to be in that violent state of vibration or oscillation associated with the hot state. These molecules set up radiant-energy waves in the ether which travel at enormous speeds in straight lines in all directions from the hot body. When such radiant-energy waves impinge on a colder body some of whose molecules can vibrate in tune with them, then the waves are absorbed by the colder body. Its temperature rises due to the increased vibration of its molecules resulting from the absorption of the radiant-energy waves. Thus radiant energy passes to all boiler surfaces directly exposed to the fire and is conducted through the metal to the boiler water inside. If the body contains only molecules which do not have natural periods of vibration in harmony with the impinging waves, the radiant energy either passes through or is reflected. Thus heat waves pass through glass without appreciably raising its temperature. On the other hand, many insulating materials such as firebrick reflect the radiant-energy waves from their surfaces and absorb little heat.

A dull black body has the greatest capacity for emitting and receiving radiant energy. A gray body, on the other hand, emits and absorbs only a small portion of the energy of a black body under similar temperature conditions. In order that heating surfaces may absorb radiant energy they must "see" the source of the radiations. This is important in adjusting the areas of boiler surface exposed to the furnace.

Certain gases also have the property of radiating heat. For instance, carbon dioxide and water vapor can both absorb and emit radiant-energy waves. Oxygen, nitrogen, and air, on the other hand, are practically inert as radiators or absorbers. Hence heat radiation from the gases plays an important part in the performance of a furnace. It is therefore necessary to study closely the laws

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of radiant heat as well as those of convection as applied to furnaces.

Stefan and Boltzmann's law of radiant-heat transfer states that for an ideal black body the amount of heat transferred varies as the difference between the fourth powers of the absolute temperatures of the hot and cold bodies. This takes the form $H = K(T_1^4 - T_2^4)$, where H is the heat transferred in unit time, K a constant depending on the nature of the surfaces of the hot and cold bodies, and T_1 and T_2 the absolute temperatures of the hot and cold bodies, respectively. Actual solids and gases follow this law more or less closely. The rapid increase or decrease of heat transfer with relatively small changes in furnace temperatures is the significant feature of this formula. Experience with furnaces has shown that it is desirable to transfer as much heat as possible by radiant energy. Hence from this standpoint, maximum furnace temperatures are desirable. Any influence which tends to lower furnace temperature should therefore be closely scrutinized and, if possible, removed so that this desired maximum temperature may be secured. This idea must be kept clearly in mind in considering designs of furnaces for pulverized coal.

NATURE OF COMBUSTION

The elements entering into the chemical reaction known as combustion are those occurring in the coal, together with the oxygen of the air. The elements in the coal as given by an ultimate analysis are carbon, hydrogen, oxygen, nitrogen, sulphur, and ash. Little is definitely known regarding the association of the carbon, hydrogen and oxygen in the coal, particularly in bituminous and lignite coals. Certain destructive changes involving distillation take place in the coal when subjected to heat, and as a result hydrogen, oxygen, and the so-called volatile carbon in various combinations are evolved. Furthermore these distillation changes take place and the resultant gases are burned before the remaining carbon of the coal, now in coke form, is consumed. Sulphur may occur as free sulphur or as pyrites, frequently the latter. Sulphur dioxide is formed by oxidation of pyrites and the free iron combines with oxygen to form Fe_2O_3. This iron oxide enters the ash and, as will be shown later, has a tremendous influence on the life and performance of the furnace walls.

The most rapid ignition and combustion possible is desired to obtain the highest furnace temperatures and thus the highest efficiency. The small powdered-coal particle entering the furnace at the burner mouth must first be heated up before combustion starts. This heating is by stages. First, any moisture in the coal must be vaporized. The drying process is endothermic or heat-absorbing. That is, the furnace walls or the burning flame must furnish this heat to raise the temperature of the incoming coal particle and to start distillation, which is the next stage. While some of this radiant heat is furnished by the surrounding walls, the greater part comes from the flames of burning coal and gases. This reverberatory action of the flames is highly important, particularly with low-volatile coals. The distillation changes start at about 400 deg. fahr., and gases and volatile vapors are given off forming smoke until combustion starts. Experiment indicates that the distillation process is also endothermic unless the oxygen content of the coal is high.[1] The entering coal particle, being a black body, readily absorbs radiant heat and increases in temperature. The primary air which accompanies the coal is a poor absorber of radiant heat and may have increased in temperature only slightly when the gases begin to distill. In fact, it is quite probable that the air is heated largely by convection from the coal particles suspended in it and which are absorbing radiant heat. The smoky gases from the coal contain carbon particles which continue to absorb radiant heat, thus increasing their temperature. Finally the air-gas mixture reaches ignition temperature and combustion of the gases commences.

The primary air now used to convey coal into the furnaces is often preheated to some extent, but rarely over 150 deg. fahr. This air is the best means for heating the entering coal and should therefore be highly preheated. This preheating will obviously shorten the time until combustion starts and will result in rapid ignition.

Returning again to the combustion process, the burning of the volatile matter produces water vapor and carbon dioxide, both of which will absorb and also radiate a considerable amount of radiant energy. The combustion of the volatile matter may be considered a step-by-step process where the hydrogen first unites with oxygen, freeing the carbon in an atomized state but highly heated by the burning hydrogen. Undoubtedly a certain amount of heat resulting from the combustion of the hydrogen is absorbed and dissipated as radiant heat by these free carbon particles, which are nearly pure black bodies and which give luminosity to the flame. Experiments have shown that luminous flames with incandescent particles of carbon floating in them radiate more heat than non-luminous flames. More radiant heat is emitted and may be absorbed from the flames of a pulverized-coal furnace than from those of an underfeed-stoker furnace due to this large volume of flame of greater luminosity. Much of the secondary combustion in the flame with stokers is due to carbon monoxide, which burns with a non-luminous flame and hence has less radiating power. The rapidity with which the free carbon particles in the powdered-coal furnace combine with oxygen depends very largely on the speed of mixing with heated air. This is also true of the coke which now forms the remainder of the original coal particle.

The speed of combustion of this coke and the consequent length of flame travel are dependent upon rapid mixing in the furnace. Unless the products of combustion of the volatile gases are swept away from the coke, it remains surrounded by inert gases. Oxygen cannot reach the particle until this gas envelope is removed farther along in the flame travel. The coke takes an interval of time to burn, and fresh supplies of oxygen must reach the coke throughout the whole combustion period. The extent of mixing necessary can be appreciated from the fact that the particle of coke must come in contact with many thousand times its own volume of air under furnace conditions, in order to burn completely. Violent mixing is thus an essential of rapid combustion and short flames. Turbulence of the mix has been found desirable for rapid ignition in solid-injection oil engines. Turbulence in the furnace seems to be an essential factor in the burning of powdered coal. Tests made on the Fuller tangential-jet furnace are said to bear out this opinion and indicate that more rapid combustion with the development of more B.t.u. per cu. ft. than is now current practice may be obtained by violent turbulence in the furnace.

It is hardly necessary to point out that finely ground coal permits more thorough mixing and more rapid combustion. Hence the desirability of fine grinding.

The combustion just described cannot proceed until the secondary air itself has been warmed up to ignition temperature, and this must be done by conduction and convection from the heated particles of carbon. This is a slow process. It will at once be evident that highly preheated secondary air is an accelerator of combustion and should therefore be employed.

Summing up the factors in the combustion process, it is desirable to use thoroughly dry and finely ground coal with highly preheated primary and secondary air. A state of violent agitation should be maintained inside the furnace to insure rapid contact of combustible and oxygen. Rapid combustion with consequent high furnace temperature and shorter flame travel than are present practice should result from the application of these principles.

FURNACE WALLS

Experience with furnaces as now designed indicates that more excess air is supplied at various ratings than is necessary for combustion, in order that the temperature may be kept within limits set by wall conditions. It would therefore appear that the desired more rapid ignition and combustion with resultant higher furnace temperature cannot be permitted with certain wall constructions. Hence an analysis of furnace walls must be made to determine what construction will prove satisfactory.

The burning coke particle in the furnace throws out great quantities of radiant heat besides that emitted by the nascent carbon during the combustion of the volatile matter. The glowing ash particle that remains after the combustion of the coke is a gray or reddish body, and therefore absorbs and emits little radiant energy. In fact, it has very little heat to give up in any case. These facts account for the relatively cool condition of the ash below the water screen. The term "water screen" has been applied to those tubes which cross the furnace above the ashpit. They form

[1] See Lander and McKay, Low Temperature Carbonization, p. 103.

part of the water circulation of the boiler and, by absorbing radiant heat, cool the falling ash and the ashpit itself. Water vapor and carbon dioxide resulting from the combustion of the coal particle are at, high temperature and, as noted before, emit radiant heat. Recent investigations[1] indicate that these radiations increase with depth of flame and in consequence may assume large proportions in the big furnaces usually employed under boilers.

Radiant heat is given off in all directions. In a pulverized-coal furnace the presence of such solid particles as coke, burning carbon, and incandescent ash particles are obstacles in the path of radiations from the interior portions of the flame and either absorb or reflect these radiations. It is therefore logical to assume that the furnace walls only affect the radiations of a relatively thin envelope of the furnace volume and that the interior of the furnace is affected but little, if any, by wall conditions. This idea is in conformity with certain researches by physicists and has been fully discussed elsewhere.[2] Such a deduction is highly significant, for it leads to the conclusion that wall temperatures cannot have much effect on furnace conditions as a whole. Hence it is possible to use water-cooled furnace walls.

Furnace walls are a vital part of the powdered-coal system and have a great effect on maintenance costs and boiler outage. Their construction must be greatly influenced by the character of the ash. The better-grade coals with high-fusing ash are becoming exhausted in many coal regions, and during the life of the stations now being built much coal may be burned that will have higher ash and higher pyritic sulphur than the coal now used. Furnaces should be designed to meet such unusual conditions.

Experiences in the Middle West with low-grade coals indicate that air-cooled furnace walls are washed away rapidly by the chemical alloying properties of liquid ash containing a large percentage of iron oxide. Such liquid ash readily combines with the silica and alumina of the firebricks to form iron-silica-alumina compounds of the series well known in the cement industry. It does not appear to be possible to stop this alloying action as long as liquid-ash particles are thrown against white-hot firebrick walls. Air cooling of side walls only becomes effective when the bricks have been washed down to thicknesses ranging from $^3/_4$ in. to 2 in. No neutral bricks have so far been tested that will stand up satisfactorily under furnace conditions and will not spall. These experiences would indicate that silica-alumina brick can only be used in air-cooled walls when high-fusing-point ash is present. When brick-lined furnaces are desired this wall may take the form of a water-tube-supported thin wall as in the Bettington boiler or of certain other forms now under development.

There is some question whether brick are needed at all in the furnace walls. More or less slag formation will always occur with low-fusing-point ash on any brick inside the furnace, and this will give trouble. Many engineers believe that brick walls are needed as reflecting surfaces to accelerate the ignition and combustion of the entering coal and that bare water-cooled walls would absorb so much radiant heat that either long flame travel will be necessary or incomplete combustion will result. It has already been pointed out that only the outer envelope of the furnace flame will be affected in any case, and even then the net cooling effect will be minimized if the air and fuel are preheated and if violent turbulence exists. In any case the front walls may be of brick according to present practice in certain systems of firing. Care must be taken in designing front walls that the brickwork properly shields all supporting steel from radiant heat. Air-cooled brick walls or brick-faced water-cooled walls may be necessary to give reverberatory action in furnaces burning anthracite, coke dust, or low-volatile coal.

Water-cooled furnaces should logically permit higher boiler capacities to be carried with a given total heating surface for the boiler unit and a given furnace volume. The radiant heat from the flames is absorbed by the metal walls and transferred directly to the water. The rate of heat absorption by radiant heat is about eight to ten times the average rate by convection. Data now at hand indicate that the rate of heat transfer by radiant heat to metal side walls may reach as high as 75,000 B.t.u. per sq. ft. per hr. In the case of brick-lined furnaces the radiant heat is reflected by the brick surfaces, and while some of this reaches the boiler tubes, much is absorbed by the gases and raises their temperature. This heat is carried up into the farther passes of the boiler where it is given up to the tubes by convection at a relatively lower transfer rate than by radiation. Hence the total heating surface must have lower capacity with brick-lined furnaces than in the case of the metal-lined furnace.

Completely water-cooled walls, both rear and side, seem to be fully warranted. The ash will have no washing or cutting effect on these, and probably little trouble will be experienced with slag. Since radiant heat is the most effective of the three methods of heat transfer, this construction should tend to produce still higher boiler efficiency, and as this furnace wall surface is highly effective as a heat absorber, less surface need be put in the upper sections of the boiler. The resulting reduction of boiler height would permit of a lower boiler room and hence a less costly plant.

There is one factor in the construction of metal side walls that does not seem to have been given any attention. It is a well-known fact that gray surfaces are poor absorbers of radiant heat and therefore are largely reflectors. If the outer surfaces of the metal tubes could be made of a light-gray material instead of black iron, the absorption of radiant heat would be decreased and the cooling effect on the borders of the furnace flame would be diminished. Calorized tubes might be tried for this service. This construction might be used where coke or anthracite are burned and less cooling by the side walls is desired.

There appear to be no insuperable difficulties in the construction of a satisfactory water-cooled furnace lining. Such construction would permit the highest attainable furnace temperatures. As stated before, minimum excess air is not employed in the brick-lined powdered-coal furnaces, for the walls will not stand the high furnace temperatures that would be developed. This limitation would be removed with metal walls and boiler efficiency would be thereby increased. A portion of one of the walls might be occupied with a radiant-energy superheater operating either alone or in series with a convection superheater.

AIR PREHEATERS

The ideal power plant with powdered coal would be one where the feedwater was heated solely by bled steam and the heat in the chimney gases recovered by air preheaters. Tests at Colfax indicate that there are gains to be made by preheating air over and above that due to the increase of air temperature. These gains appear to be due to the more efficient transfer of heat by radiant energy as a result of higher furnace temperatures. Furthermore it will be apparent that this air should be preheated to as high a temperature as can be secured. While air preheaters are still in the development stage, satisfactory progress has been made already and improved designs can be expected.

Attempts have been made to preheat air by bled steam. The use of heaters similar to those now in use for cooling generator air have been considered for this service. There are possibilities of slight gains in plant economy by this process. Insufficient data are available on heat transfer in such heaters at high temperatures, and performance cannot therefore be definitely predicted. The scheme warrants further study.

COAL DRIERS

Coal drying is desirable as previously pointed out, aside from the fact that coal transports better when thoroughly dried and that seasonal difficulties from frost and snow are eliminated. Coal may be dried by three methods: It may be furnished from some outside source with sufficient heat to raise its temperature to the point where its water content will vaporize, force itself out to the surface of the lumps, and separate out as steam. This process is used in certain rotary driers. A second process is to pass heated gases through the coal and evaporate its moisture content by humidifying the gas. The controlling factor in this method is the wet-bulb temperature to which the coal is heated while evaporation takes place, and not the dewpoint as some have stated. This plan is used in the waste-heat driers and steam driers now in use. The third method is a combination of the two previous methods and is employed in the standard rotary drier. The outer shell is

[1] New Data on Heat Radiation, MECHANICAL ENGINEERING, January, 1925, p. 41.

[2] The Influence of Radiant Heat on Furnace Design, *Power*, May 29, 1923, p. 851.

heated by the fire and by the hot gases which afterward pass through the driers, evaporating moisture according to the second method.

The first method, while commercially practicable, is not as efficient as the other two. It is used generally for drying substances that cannot be allowed to come in contact with flue gases. It is not recommended for pulverized-coal plants.

The third method, employing the rotary drier, was formerly used in all powdered-coal plants. It is an effective means for drying coal and can reduce the moisture content of the coal to a low figure. The objections to its use are the amount of space required to house it, the fuel required for drying, and the dust nuisance from its waste gases. Thoroughly dry coal can be pulverized in screen mills with a smaller expenditure of power than in air-separation mills. This fact coupled with the advantage to be derived in the furnace from thoroughly dry coal may more than offset the other disadvantages of the rotary drier. This system has been adopted in some recent installations whose performance will be followed with interest.

The second system has been installed in many plants. Its operation is not so well understood as those just discussed and its limitations must be fully considered. The waste-heat drier uses a portion of the flue gases from the boiler. These are drawn by a forced- or induced-draft fan through a layer of coal usually less than a foot thick. The evaporation of moisture tends to saturate the gases during their passage through the coal.

Hot spots were frequent in some of the first of these driers used on high-sulphur coal. At first it was thought undesirable to admit high-temperature gas to these driers and the gas was therefore diluted with air, which provided oxygen to start spontaneous combustion of coal dust on ledges and elsewhere in the drier. The practice of diluting with air was abandoned when it was realized that the coal remains at wet-bulb temperature while evaporation takes place, and thus practically throughout its whole passage through the drier. Flue gases as hot as available are now used. The oxygen content in these gases is too low to start fires and the troubles of spontaneous combustion have disappeared.

Certain difficulties still remain. Some coals readily give up their surface moisture but, either from lack of capillarity or due to the presence of combined water, give up little of their interior moisture. When such coal reaches the pulverizers the work of attrition in crushing to small size liberates the water, so that these mills and their cyclones have to be well vented to remove this moisture. These vents discharge some coal dust, which adds to the dust nuisance.

However, for low-moisture coals, particularly where this moisture is largely on the surface, such driers are quite satisfactory. Some development work must still be done on these driers to insure more thorough drying with a smaller quantity of flue gases. Two passes for the gas have been suggested. The first pass of the hot gas would be through the cold entering coal and the second pass lower down through the coal about to leave the drier. Neither coal nor gas would then fall below wet-bulb temperature. This would require less gas than the single pass and would insure more thorough drying. The coal stream could be made thinner than present practice.

Steam driers are used in certain cases where waste gases are not available and where low-pressure or bled steam can be had. Air is drawn through a set of nested heating grids which form the chute down which the coal passes. Coal is a poor heat conductor, hence little will be heated above the wet-bulb temperature of the entering air. This wet-bulb temperature will be much lower than that of the flue gases in the waste-heat drier, and although oxygen is present, there is little danger of fires at this low temperature.

Ash

Certain coals have such high-fusing-point ash that no difficulties are experienced from this source at any ratings that may be carried on the furnace. Hence these plants can operate with hollow-walled brick furnaces and simple ash-handling equipment. However, as already pointed out, many stations may be compelled during their life to use lower-grade fuels often containing a high percentage of pyritic sulphur, and this must be considered in the design of the plant. Such ash slags and washes badly on brick walls. However, it will probably adhere little to water-cooled walls, and while occasional clinkers may form on the water screens and on the lower boiler tubes, these can generally be easily removed.

A portion of the low-fusing ash forms sharp, sand-like particles which fall to the bottom of the furnace together with some ash dust. The removal and transport of this ash present some problems. Its abrasive properties have proven destructive to ducts where water flushing has been employed. It would be difficult to remove this material in a dry state on account of its high temperature and dust. Steam-jet ash transport is uneconomical of steam and requires a large make-up for the station. Some new and better scheme of handling the ash from the furnace bottom must still be devised.

Some of the finer dust particles that pass through the boiler may be caught by cindervane fans. The very fine particles have been allowed to pass up the chimney to be discharged at the top with the flue gases.

Engineers have already done much to lessen the dust nuisances of all our large cities, but more can still be done. It should therefore be a public duty to reduce as far as possible the discharge of dust and smoke from chimneys of stoker plants and of those using pulverized coal. Such dust floating in the air lessens the amount of sunlight reaching the surrounding earth, increases fog conditions, increases the cost of keeping cities clean, increases disease, and lessens the health and vitality of those who breathe the air it contaminates. There are thus good social reasons for minimizing the discharge of dirt from chimneys of all kinds, including locomotives.

Several methods have been proposed to catch this ash in new super-power plants. Washers lower the gas temperature and lessen the effectiveness of the chimney as a draft producer. Their success in cleaning air, however, warrants further experimenting on flue gases. The Cottrell electric precipitation system works satisfactorily on cement dust and is said to be efficacious as a remover of ash from the flue gas at the Trenton Channel plant of the Detroit Edison Company. Other schemes have also been proposed but have not been fully demonstrated. This whole question of dust nuisances has not been given as full attention as it deserves.

The fine dust from chimneys should find some commercial use in the industries either as a filler for paints, fertilizer, or other products, or as a base for some building material. Such uses will undoubtedly be found in the near future, for much money has been spent on development work.

Conclusions

This analysis of boiler furnaces for pulverized fuel indicates that for highest efficiency and maximum capacity:

(*a*) The coal should be thoroughly dry, and be finely ground and preheated before admission to the furnace.

(*b*) The air entering the furnace should be highly preheated, and this can be done best by flue gases, although there are possibilities in the use of bled steam.

(*c*) Turbulence should be maintained in the furnace to insure rapid combustion and high efficiency.

(*d*) The furnace walls should be water-cooled, preferably with all-metal walls. This construction insures low boiler outage, low maintainence, and high efficiency of heat transfer. Water-cooled walls with brick facing may be desirable with certain fuels.

(*e*) Improved methods should be developed to handle ash from any coals, and the discharge of dust and smoke from the top of all chimneys should be reduced.

(*f*) To secure increased furnace capacity and at the same time secure higher boiler efficiency, more B.t.u. per cu. ft. of furnace volume must be developed. This is possible by employing the factors noted above.

Discussion at the Pulverized-Coal Session

THREE papers bearing on different phases of pulverized coal were presented at a session under the auspices of the Fuels Division at the Milwaukee meeting of the A.S.M.E., with John Anderson of Milwaukee in the chair. Professor A. G. Christie[1] wrote on Boiler Furnaces for Pulverized Coal; a paper on Radiation in the Pulverized-Fuel Furnace, by W. J. Wohlenberg[2] and

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Donald G. Morrow,[1] was presented by George A. Orrok[2] in the absence of the authors; and L. V. Andrews[3] read an abstract of his paper on A Microscopic Study of Pulverized Coal.[4] An abstract of the discussion on the paper by Christie and the one by Wohlenberg and Morrow follow. The discussion of the Andrews paper is to be printed in a subsequent issue of MECHANICAL ENGINEERING.

DISCUSSION OF THE CHRISTIE PAPER

C. G. Spencer[5] opened the discussion of Professor Christie's paper with some comments on the metal-lined pulverized-fuel furnace at Cahokia. During a period of eight weeks, he said, the boiler had not been taken off the line because of furnace trouble. The performance was a confirmation of Professor Christie's analysis, showing a decrease in furnace temperature, no slagging when operating at a higher CO_2 than could be safely carried in furnaces not metal-lined, and no fouling of the metal lining.

W. J. Wohlenberg, in commenting on a statement of the author's in Par. 5 to the effect that firebrick reflect the radiant-heat energy waves from their surfaces and absorbed little heat, wrote that the reason lay in the fact that refractories were poor conductors rather than good reflectors of heat, and that the energy emitted from such surfaces was, for the most part, re-radiated in all directions, rather than reflected in one.

The author's assumption in Par. 21 that the furnace walls affect only the radiations of a relatively thin envelope of the furnace volume was pointed out by Professor Wohlenberg to be true only if the average wall particles were very much smaller than they actually are, the higher temperature of the interior of the flame being more probably due to a higher rate of energy liberation.

H. W. Brooks[6] discussed the importance of the rapid mixing of gases in the furnace and quoted some figures to emphasize the difficulty of the problem. He presented a series of slides showing the "well type" furnace, which was developed with the idea of increasing turbulence and installed in experimental form at the Sherman Creek plant of the United Electric Light and Power Company of New York.

C. W. E. Clarke[7] also wrote of the statement in Par. 21 about the slight effect on the furnace temperature as a whole of the heat radiated to the furnace walls. If the gases entering the first pass were at the same temperature for both air- and water-cooled side walls, he wrote, then the amount of surface in the upper parts must be the same per pound of gas passing through the boiler. If a very considerable amount of heat were absorbed by surfaces in the furnace walls, the furnace temperature would have to be materially reduced or else more heat would have to be produced in the furnace. The distribution of the amounts of heat absorbed through the boiler was materially changed by the introduction of considerable surface exposed to radiant heat. The efficiency of these radiant-heat surfaces would be considerably higher, but the efficiency of the convection-heat surfaces might be reduced to offset it.

Mr. Clarke also pointed out what he considered to be a difficulty in the influence of the color of the water-cooled surfaces on efficiency of the surfaces in that the walls took their color from particles of ash and dust adhering to them and hence the color would be hard to control.

Accompanied by a number of slides, Mr. Clarke gave some figures comparing the operation of the plants of the Allegheny County Steam Heating Company and the Colfax station of the Duquesne Light Company. Experience at Colfax, he said, had demonstrated the impossibility of using, with pulverized coal, the ordinary type of air-cooled setting with preheated air.

E. G. Bailey[8] wrote that he thought the author had reached a wrong conclusion in Par. 21 in advocating cold furnace walls. While 90 per cent of combustion might take place in 10 per cent of the furnace volume, it was important that the temperature of the carbon particles for the remaining 10 per cent should not be cooled below ignition temperature.

With the advent of turbulent burners, he wrote, hot walls would still be necessary. While the furnace volume would be materially reduced, so would the luminosity of the flame; and there would always remain the problem of burning the last one per cent of carbon floating in a transparent atmosphere where the percentage of oxygen was so low that heat could not possibly be developed as fast as it would be radiated to cold surroundings.

J. Gould Coutant[1] wrote that after having read the papers by Professor Christie and by Professor Wohlenberg and Mr. Morrow, he realized more than ever the elusiveness of the problem. He brought out the importance of the fusing point of ash in determining furnace temperatures. He also presented a chart for determining the theoretical temperature of gases in boiler furnaces and a sketch of a constant-temperature furnace.

A. R. Mumford[2] also took exception to Professor Christie's statement about the effect on furnace temperature of radiation from the outer envelope of the flame. He was, he wrote, an advocate of water-cooled walls because of their obvious structural advantage and from the standpoint of the reduction of radiation and convection losses from external setting surfaces. He felt that water-cooled walls affected a pulverized-coal flame adversely and that this adverse effect could be overcome by a study of the proper relation of the quantity of primary air to coal in order to maintain the maximum rate of flame propagation under any given set of conditions.

In closing the discussion, Professor Christie said that both he and Professor Wohlenberg were attempting to say the same thing when he talked about reflected and Professor Wohlenberg about re-radiated heat. Besides the effect of the coal particle itself, he thought that CO_2 and water vapor should be taken into account.

He was interested in the new type of furnace mentioned by Mr. Brooks and was familiar with the Sherman Creek development.

With reference to the objection Mr. Clarke had made about the effect of color on water-cooled surfaces, he said that in the newer furnaces there had been little adherence of slag and therefore color would have an effect.

DISCUSSION OF THE PAPER BY WOHLENBERG AND MORROW

After presenting the paper by Professor Wohlenberg and Mr. Morrow, Mr. Orrok took occasion to discuss it. He said that he had been greatly pleased to find in the paper for the first time a coefficient which would indicate what proportion of the heat evolved in burning a pound of coal in a furnace went into radiant surfaces.

This was the coefficient μ_4. He then showed a slide in which he had plotted the values of μ_4 and an empirical formula by Hudson which he had been using for some time.

H. W. Brooks made objection to the statement by the authors that with present systems finer pulverization probably would not increase the rate of energy liberation.

B. N. Broido[3] wrote that he had tried to compare by means of the authors' formulas and by test the heat absorbed by radiation in a boiler. The results had not checked closely, but this might have been due to possible errors in the rather complicated formulas. It might be possible to simplify these calculations and make them more adaptable for general use. He deplored the general lack of data and research on the matter of radiation in furnaces, and the use of empirical formulas.

In closing the discussion, Mr. Orrok said he was sorry that more had not taken part in it. In answer to Mr. Broido, he said that engineers were in need of simple formulas which would give the results quickly. They prepared rational formulas, but when these contained too many unknown quantities, were difficult to solve, and resulted in solutions no more accurate than those found by empirical formulas, engineers would use the empirical formulas. He had used Hudson's formula in more than 60 cases, and where the radiation and unaccounted-for information did not exceed 5 per cent, the formula would check up within 2 per cent.

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[4] See MECHANICAL ENGINEERING, vol. 47, no. 5, May, 1925, p. 429.
[5] McClellan and Junkersfeld, New York, N. Y. Mem. A.S.M.E.
[6] Consulting Engineer, Fuller-Lehigh Co., Fullerton Pa. Mem. A.S.M.E.
[7] Consulting Engineer, Dwight P. Robinson and Company, Inc., New York, N. Y. Mem. A.S.M.E.
[8] President, Bailey Meter Co., Cleveland, Ohio. Mem. A.S.M.E.

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[2] Fuel Engineer, New York Steam Corp., New York, N. Y. Assoc. Mem. A.S.M.E.
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Principles of Metallurgy of Ferrous Metals for Mechanical Engineers[1]

IV—Heat Treatment

By LEON CAMMEN,[2] NEW YORK, N. Y.

THE knowledge of the fundamental principle of heat treating goes back into the mists of prehistory. Homer, some ten centuries before the beginning of our era, describing the blinding of Polyphemus, said, "And as when a smith dips a great ax or adze in cold water amidst loud hissing to temper it—for therefrom comes the strength of the iron—even so did his eye hiss around the stake of olive wood."

The big things metallurgists have since learned have been, first, how to heat treat material more effectively, secondly, that not always "therefrom comes the strength of the iron," but instead, that improper heat treatment may weaken the material rather than strengthen it.

From what has been said in the first two chapters of this series, it would appear that the properties of a material depend primarily upon two factors, its chemical composition and its structure, the latter being taken in the broad sense to cover both the crystalline and the intracrystalline distributions of material. Either the chemical composition of steel or its structure can be changed within wide limits, even after the steel has reached the solid state.

Experience has shown that steel of any given analysis attains its desirable properties at a certain composition and structure, and further, that steel as cast very seldom possesses these desirable chemical compositions and structures. The problem of the metallurgist is therefore to take the material as produced by casting, rolling, or forging and by means of heat treatment impart to it that chemical composition and that particular structure which will give it the desirable qualities. Roughly, it has been found that the desirable qualities may be imparted to a steel of given analysis by either heating it to a given temperature or beyond and then cooling it to that temperature, and by subsequently "trapping" the composition and structure of the metal which have been created at that temperature or at a certain given one below it.

The need for heat treatment may originate in several ways. When a casting is poured in its mold its rate of cooling obviously depends on the thickness of section, a heavier section cooling at a lower rate than a thinner one. Furthermore the loss of heat from the casting is practically beyond the control of the foundryman. As a result of these two conditions, it is only very rarely that a casting has the same grain structure throughout, and it is equally rare that the temperature conditions and rate of cooling during the solidification and subsequent chilling of the casting are such as to produce exactly the right structure therein. It usually happens that the wrong structure is produced instead, and heat treatment has to be called upon to correct this state of affairs.

In the case of alloy steels particularly, it is often absolutely essential in order to impart the necessary properties to heat the material to a certain temperature and to cool it in a certain manner or at a rate entirely different from that prevailing in a casting when chilled in the mold. A good example of this is the well-known case of high-speed tool steel.

Another important instance where heat treatment is essential is in the case of materials which have to be first soft and then hard. Such is the case of ball-bearing races. This material must be soft initially in order to permit the cutting, trepanning, and machining in the automatic, but afterward must be extremely hard in order to withstand the mechanical stresses imposed upon it and the cutting action of the hard balls.

A third group of cases where heat treatment is essential has to do with metal wherein hardness has been induced by cold working.[1] Thus in cold-drawing tubes a single pass through the dies hardens metal which was quite soft before the operation to such an extent that if it were attempted to put it through the next pass on the bench without previous treatment it would not flow but would crack. In all such cases it becomes necessary to submit the metal to some operation that will make it softer.

It has also been found that heat treatment, in addition to changing the hardness of a metal, may increase or decrease its tensile strength, resistance to vibration, and other properties. In fact, there are many instances where heat treatment produces some of these effects without materially changing the hardness of the metal. Such for example, is the case with the so-called Hadfield manganese steel.

From what has been said in Chapter III, dealing with the structure of steel, it appears fairly clear why heat treatment produces these various effects. To recapitulate in a somewhat different form the information given in that chapter, it may be stated that these effects are produced by two factors: At certain high temperatures all ferrous materials are essentially solid solutions of carbide of iron and carbides (and possibly other combinations) of the alloying elements in certain allotropic modifications of iron. No matter what the structure of the material may have become at room temperature, as an effect of mechanical working or previous thermal influences, this structure may be, at least for a given material, and often is, completely destroyed by passing the material into the state of solid solution, just as the shape of lumps of sugar may be destroyed by throwing them into a cup of water. When the material has been, in a certain suitable manner, subsequently returned to room temperature in the case of iron, or crystallized by evaporation of the water in the case of sugar, its new structure will be far more affected by the process adopted for developing it from the solution, be it solid or liquid, than by its life history previous to its entrance into the state of solution, and may be entirely independent of this previous history. It will be shown later that in practically all heat treatment it is necessary to heat the metal through the "upper critical point," and it will also appear at that time that this "point" represents the temperature range at which the entire metal passes into a state of solid solution. This is the first of two factors lying at the foundation of all heat treatment, and its importance lies in the circumstance that it provides a means for "wiping the slate clean" by doing away with all, or at least most, of the previous structure of the metal, and thus permits building up the new and desirable structure. The second factor is the change in the crystalline structure of the material expressed by the molecular rearrangement within the crystals, which partly covers the allotropic phenomena and also the rearrangement of the grains. There is every reason to believe that concomitant modifications of the intercrystalline cement take place and powerfully affect the resulting properties of the metal, but our knowledge of this is too scant as yet to warrant any statement as to the nature of these variations.

An attempt will now be made to give an insight into what may be called the secret of discovering the proper method of heat treating a ferrous alloy, and it is desired to lay emphasis on the statement that this chapter has not been written with the view of teaching the art of heat treatment to those who expect to practice it, but merely to explain its fundamental principles to engineers, who, in the course of their work, have to deal with heat-treated products or specify them for mechanical constructions.

Critical Points

It has been found that in cooling such iron alloys as the majority

[1] Fourth of a series of articles discussing the underlying physical and chemical processes involved in the metallurgy of iron and steel. The first, dealing with the physico-chemical properties of iron alloys, appeared in the May issue, p. 339, the second, on the crystalline structure of ferrous metals, in the June issue, p. 479, and the third, on determination of the properties of metals, in the July issue, p. 559.

[2] Associate Editor, MECHANICAL ENGINEERING.

[1] The theory of this was briefly explained in the chapter dealing with the crystalline structure of metals, MECHANICAL ENGINEERING, June, 1925, pp. 482.

of steels, the cooling proceeds for a while so that as the temperature of the piece falls off the cooling is gradually retarded. When, however, a certain point is reached the piece not only stops losing in temperature, but under certain conditions actually appears to get hotter. Then after an interval the fall of temperature is resumed, only to be stopped again, and perhaps even a third time. On heating a steel bar the phenomenon is reversed. With the addition of heat to the piece it becomes gradually hotter and hotter, then more or less suddenly it stops gaining in temperature—and under favorable conditions may even lose—and this phenomenon may occur once, twice, or even three times as the temperature of the piece rises.

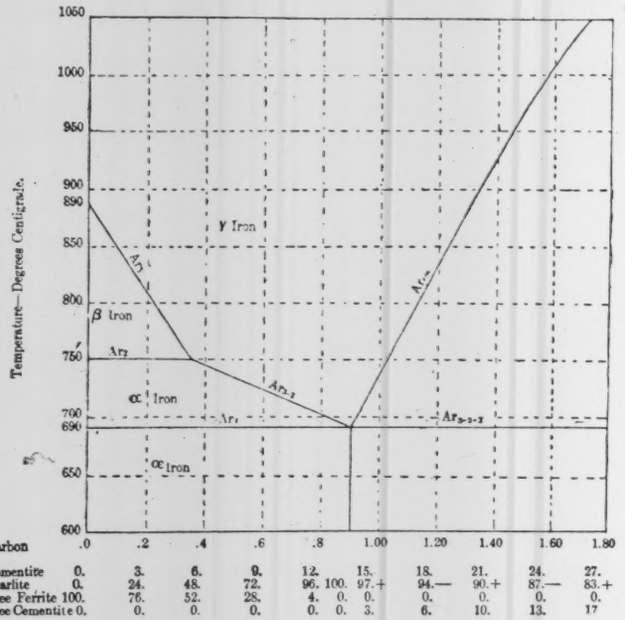

Fig. 11 Diagram Showing Position of the Critical Ranges and the Relation of the Carbon Content to That of Pearlite, Ferrite, and Cementite

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Mechanical engineers are familiar with a somewhat similar phenomenon: In heating water, when it reaches the boiling temperature for a given pressure it begins to absorb heat without change in temperature. In the case of water this is called the "latent-heat absorption;" we know now, however, that this heat is not at all latent, or rather that it is latent only in so far as the thermometer is concerned, but is engaged in doing internal work, namely, pushing the molecules of water apart until they are drawn away from each other so far that the water is converted into steam. In other words, heat during the so-called latent absorption stage is employed in effecting an internal rearrangement of the particles in the mass of water that results in its vaporization. Conversely, when steam is condensed to water of the same temperature, a large amount of heat is evolved due to an inverse rearrangement of the molecular structure of the mass.

Exactly the same thing occurs in the case of steel, though in not quite so simple a manner. To show this, we may consider the case of a low-carbon steel, such as one containing 0.2 per cent carbon, slowly cooled from the molten condition to atmospheric temperature. This case has already been discussed to a certain extent in Chapter I (Mechanical Engineering, May, 1925, p. 345), and the line *yx* to represent it was drawn on the constitutional diagram of the iron-carbon system on the same page. As the metal is slowly cooled from the molten condition to atmospheric temperature, it would appear that at the start we have a liquid solution of iron and carbide of iron (at least we assume so), and that at a certain point solidification of the mass occurs. The modern theory is that iron solidifies as delta iron (body-centered cubic lattice) and inverts at 1410 deg. cent. or thereabouts to the gamma variety, at which time a solid solution of gamma iron and carbide of iron is formed, called austenite. The range within which this solution is stable lies between the point where *yx* crosses *AE* and the point where it crosses *GI*. Within that range the entire metal is solid and is a mixture of austenite and gamma iron.

When the metal cools down to the temperature corresponding to the point where *yx* crosses *GI* (about 840 deg. cent.), a change occurs in its structure in that some of the gamma iron is deposited out in the form of beta iron, while the rest remains in the form of austenite. The conversion of gamma iron into beta iron is accompanied by a rearrangement of the atoms within the crystals of the metal (explained in detail in Chapter II, June issue of Mechanical Engineering), and is accompanied by a certain evolution of heat which either stops the cooling or may even result in a reheating of the mass called "recalescence."

As to the cooling of the mass, which consists now of beta iron and austenite, proceeds, a temperature is reached indicated by the line *MI*. This is the lower limit at which beta iron can exist, and when this is reached a new change occurs, the beta iron being converted into alpha iron, which results in a further evolution of heat and is another instance where the continuing loss of temperature from the metal through convection, conduction, and radiation does not show on the thermometer.

Below the line *MI* no more beta iron can exist, so that in the section between *MI* and *PS* we have a mixture of gamma-iron solid solution with a steadily increasing content of crystals of alpha iron. As far as we know, alpha iron is the last allotropic modification of iron and is stable at all temperatures below the second point of transformation. But as the iron is cooled still further and the line *PS* is passed (about 750 deg. cent.), the gamma-iron solid solution is transformed into the eutectic mixture of alpha iron and cementite, the latter forming pearlite, so that ultimately the metal consists of alpha iron and pearlite. The transformation from gamma-iron solid solution into the new pearlitic structure is again accompanied by the evolution of heat.

We thus see that in the case of a low-carbon steel, such as a 0.20 per cent one, subjected to slow cooling there are three transformations accompanied by evolutions of heat: The first, called Ar_3, occurs when gamma iron breaks down to beta iron, the second, Ar_2, when beta iron breaks down to alpha iron (the existence of this point is doubted by some investigators), and the third, Ar_1, when austenite passes into pearlite.

The process may be reversed and we may take a pearlitic steel, say, at room temperature and reheat it, in which event the first step will be the transforming of the pearlite into austenite, the second, alpha iron into beta iron, and so on, each transformation being accompanied by an absorption of heat and hence a retarded rise in temperature or possibly even a fall in temperature. We shall then have three points each way which are called Ar_1, Ar_2, Ar_3 and Ac_1, Ac_2, Ac_3, the letters "r" and "c" standing for the French words "refroidissement," meaning cooling, and "chauffage," meaning heating. The critical points Ar and Ac do not occur at exactly the same temperature, Ac being generally situated some 20 to 40 deg. higher than Ar. Some doubt, however, has been thrown on the precision of measurements which have given this result. Such measurements are very difficult to make, and moreover it should be clearly borne in mind that what we refer to as "critical points" are not really points at all, the allotropic transformations to which their existence is due being not instantaneous phenomena but processes taking place throughout the mass of metal, and therefore requiring a certain amount of time between their beginning and end. Various investigators have used temperature records taken at different stages of the process, so that in comparing published results it is necessary to ascertain the method of measurement. Moreover the position of the critical points is affected by such factors as speed of heating or cooling and temperature from which cooling begins. The mechanical engineer, however, is not likely to have to deal with such refinements of the practice of determination of the critical points of steel.

In the above discussion of the critical points of steel we have been dealing with very low-carbon steel, because in such steels the occurrence of the critical points is spaced so as to make them more clearly distinguishable. As the amount of carbon rises the point A_3 is gradually lowered until it merges with A_2. It may then be denoted as $A_{3\text{-}2}$ (cp. line *zw* in Fig. 5 referred to above). As the carbon increases still further and reaches the eutectoid-steel pro-

portions (0.89 per cent) there appears to be only one point, all of the points being merged into it. This may be denoted as $A_{3\text{-}2\text{-}1}$. Finally, in hypereutectoid steel there is also apparently only one critical point, denoted at times by A_{cm}, where "cm" stands for cementite. This point is rather difficult to detect.

A very comprehensive set of determinations of the critical points of iron and steel was made by Carpenter and Keeling. Their results are tabulated on page 168 of the Metallography and Heat Treatment of Iron and Steel by Prof. Albert Sauveur of Harvard University, 2nd edition, 1916. The table includes the critical points occurring during the solidification period of the various steels and irons investigated, these having a carbon content ranging from 0.01 to 4.50 per cent.

As has been stated above, the cause of the appearance of the various critical points lies in the internal transformations which take place at the given temperatures, and these transformations may be either from gamma to beta to alpha iron or vice versa, or from austenite to pearlite or vice versa. It has been shown that these transformations are accompanied by the evolution or absorption of heat, depending on the direction of the reaction, i.e., whether the transformation takes place during the cooling of the piece or the heating thereof. It has been found that the rearrangements of molecules which accompany such transformations have effects other than the evolution or absorption of heat and that they affect other properties of the materials. Among the properties thus affected is, e.g., dilatation. Taking steels with a carbon content below 0.35, i.e., those having at least two points clearly distinguishable and possibly three, the following is found: At Ar_3 the metal which has been contracting, as is usual with bodies undergoing cooling, begins suddenly to expand, the dilatation amounting to over $^1/_{1000}$ of its length. This dilatation is immediately followed again by a normal contraction. Harbord and Hall, in describing the operation of a Morgan Construction Co. continuous bar mill state: "The bars, which are in lengths up to 300 ft., show the point of recalescence in a very clear manner, contracting rapidly at first, the contraction then gradually decreasing till it ceases entirely, and in a few seconds the bars begin to lengthen, slowly at first and then more rapidly; this soon ceases, and the final contraction sets in. The expansion while cooling often amounts to 2 or 3 in. on bars over 200 ft. long, and the movement is sufficiently rapid to be easily followed by the eye." (The Metallurgy of Steel, F. W. Harbord and J. W. Hall, 7th ed., 1923, vol. 2, p. 375.)

As the point Ar_3 marks also a passage from gamma to beta iron, it would appear that the latter is less dense. The electrical conductivity also changes, in that above Ar_3 the metal has a very high electrical resistance, which decreases only very slowly until Ar_3 is reached, and then begins to decrease rapidly. There are several other changes of lesser importance. The changes at Ac_3 are practically the reverse of those at Ar_3. The changes at Ar_2 are less sharply noticeable, with some exceptions, however. Dilatation does not seem to take place at all, or if it does, it is very slight. There is, however, a very striking change in magnetic properties in that above Ar_2 steel is not magnetic, but in passing through Ar_2 it suddenly becomes strongly paramagnetic. In steels of a higher carbon content, namely, from 0.35 to 0.89 per cent, the points A_3 and A_2 gradually merge, the metal passing through a joint point $Ar_{3\text{-}2}$ or $Ac_{3\text{-}2}$, at which there occurs a marked dilatation, a sudden decrease of electrical resistance, and a gain of magnetism.

At Ar_1, which occurs as a separate point in steels containing up to 0.89 per cent carbon, the transformation is from austenite to pearlite. At this point the following sudden changes in properties are noted: (1) A dilatation takes place which increases with the carbon content, reaching a maximum with 0.85 per cent carbon; (2) Increased magnetism takes place for all steels on cooling through this point; (3) A marked decrease in electrical resistance is also noted on cooling through this range; (4) Below this point iron loses entirely its power to dissolve carbon.

We come now to the application of the information given above on the critical points of steel to practical problems. Such problems may be of several different kinds. We may have a casting that the microscope and other investigations show to be coarsely crystallized, hard in spots, and therefore difficult to machine, or of undesirable structure in other ways. The problem is then to find a process which will give the metal softness and change its structure generally in such a way as to endow it with high strength, good elastic limit, and reasonable ductility. The problem may be also that of increasing the hardness of a material instead of reducing it. Then again, particularly with alloy steels, it may be necessary to give the steel a structure at which this particular metal possesses its best properties, the matter of the degree of hardness being then more or less secondary. It may also happen that in the process of casting, rolling, forging, or other treatment strains may develop in the metal, and it may be necessary to remove these strains. It should be clearly understood here that the above does not exhaust all the problems in the solution of which resort is made to heat treatment.

We may start with the process called "annealing," which may be

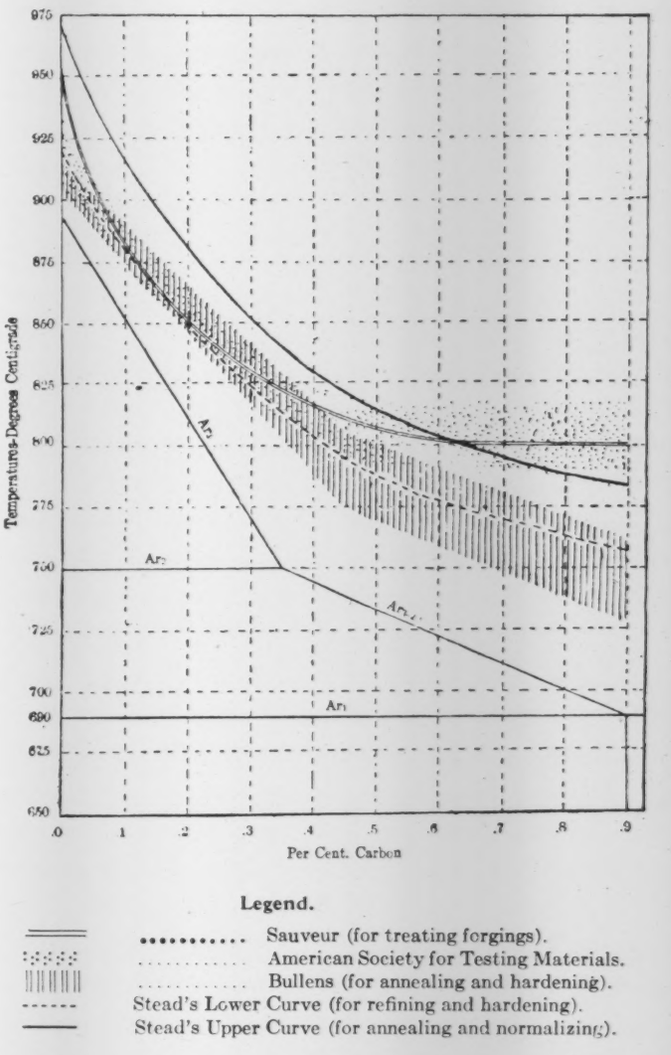

FIG. 12 ANNEALING (AND HARDENING) RANGES SHOWING APPROXIMATELY THE TEMPERATURES RECOMMENDED BY DIFFERENT AUTHORITIES

(Reproduced from The Making, Shaping and Treating Steel, J. M. Camp and C. B. Francis, 2nd ed., by courtesy of Carnegie Steel Company, Pittsburgh, Pa., publishers.)

defined as heat treatment followed by relatively slow cooling, as in an oven. A modification of annealing called "normalizing" consists of heat treatment followed by an intermediate cooling operation, as in room temperature. Both annealing and normalizing consist of three operations: (1) heating the steel; (2) keeping its temperature constant at the annealing temperature for a certain period of time; and (3) cooling it from the annealing to atmospheric temperature.

As to heating, it should be such as to permit the metal to start with what might be called a "clean slate" in reference to its structure. When the metal is chilled from casting, be it in a sand mold or ingot mold, or when it has undergone cold working, a certain structure is imparted to it as the result of the mechanical strains

or the various rates of cooling. This structure may be uniform throughout the piece or different in various parts; for example, in an ingot the structure of the outer shell usually differs quite materially from that of the core. The only way to obtain a uniform structure seems to be to obliterate all former structures, no matter what they may be, and to bring the piece to a uniform "base" structure from which, by a proper method of rebuilding, a new structure can be obtained such as will give the metal the desired qualities. In the case of carbon steels the proper procedure is to go back to the stage where the steel consisted entirely, let us say, of austenite, which is above the upper critical point Ac_3 in the case of low-carbon steel (0.35 per cent carbon and less), $Ac_{3\text{-}2}$ in the case of steel containing from 0.35 to 0.9 carbon, and $Ac_{3\text{-}2\text{-}1}$ in hypereutectoid steels.

If the steel is heated below this range no structural change takes place. (There are, however, a few exceptions to this, such as the case of cold-worked hypoeutectoid steel when the distorted ferrite may be restored to its normal crystalline structure by heating slightly below the critical range, as cited by Prof. Albert Sauveur in The Metallography and Heat Treatment of Iron and Steel, 2nd edition, 1916, p. 232.) On the other hand, it is not desirable to carry the temperature of heating very much above the critical point as this tends to coarsen the ultimate structure of the metal. It is because of this that, in annealing, steel should be heated just through the critical range, which means that the temperature of the critical point should be previously ascertained. This may be done either by direct measurement of the temperatures of bars from which known quantities of heat are abstracted or to which known quantities of heat are added, or it may be done by the measurement and simultaneous recording of temperature and dilatation, valuation of electrical conductivity, magnetic properties, etc.

As regards the duration of annealing, the article should be kept at the annealing temperature long enough to be "soaked through," i.e., heated clear through to that temperature. According to the Committee on Heat Treatment of the American Society for Testing Materials, an exposure of one hour should be long enough for pieces up to 12 in. thick. It is very important that annealing should be carried on at a uniform temperature. Coming now to the question of cooling from annealing temperature, this latter depends entirely on the properties which it is desired to give to steel. Austenite cooled with great rapidity, as in quenching, generates martensite, which is extremely hard and lacks in ductility. With a cooling quite rapid but less so than quenching, sorbite is produced, which combines a considerable amount of hardness—inferior, however, to the martensitic structure—with a certain amount of ductility and great tensile strength. A still slower cooling leads to the formation of the pearlitic structure, which is soft and highly ductile but lacks in the matter of strength. This is, however, only a general rule which is modified largely by a number of factors such as size of object, etc. A very important factor is the carbon content, as the lower the carbon content the more rapid may be the cooling from the annealing temperature without creating excessive hardness, this being obviously due to the fact that even if the carbide of iron is converted into hard martensite, this latter will be embedded in such a predominant matrix of soft ferrite that the ultimate properties of the metal will be determined by it.

A good deal of the success of the annealing operation depends on the initial structure of the metal. If the grain size in the piece is fairly good to start with, i.e., not excessively coarse, the annealing is simple. If, however, it is very bad or if the material dislocation of the structure of the metal has been produced by mechanical working, special annealing methods may have to be resorted to. The particular feature of these annealing methods is that the length during which the piece is held at the annealing temperature and which under normal conditions for pieces up to 12 in. thick need not extend beyond one hour, may in exceptionally bad cases have to be very long, running into days at times. This is only natural because rearrangement of molecules in solid matter is always a slow process and if these molecules have to travel a long path, or if the arrangement requires a more than usual amount of displacement, a suitable length of time has to be provided. It would further appear that the greater the internal stress upon the steel, the greater is the amount of intermolecular lag or final release of this stress beyond the actual change of constituents; i.e., even though a totally new structure may be set up by the annealing, there remains for a considerable length of time a tendency of the new structure to return upon slow cooling to the stressed condition of the original, even though the constituents themselves may be those born at the new temperature. Denison K. Bullens (Steel and Its Heat Treatment, 2nd edition, 1918, p. 135) explains this by phenomena of diffusion and shows a series of interesting photographs illustrating progressive absorption of the excess ferrite between the lower and upper critical ranges.

At times overheated steel has to be refined. The success or failure of this operation depends on the size of the piece and on the degree of overheating. Small pieces may be refined by a long and thorough saturation at the ordinary annealing temperature. In the case of large sections the success of annealing is much more doubtful and although the steel in general may have after annealing a fine-grained structure, large grains or "islands" may persist here and there, and under certain conditions cause trouble. If the steel has been very badly overheated or burned it is practically impossible to bring it back to a good structure. Bullens, in his work quoted above, p. 147 (Fig. 130), shows a photograph of a 10-in. shaft which was badly overheated and then underwent eight annealings at various temperatures, totaling some 200 hr. of heat saturation. Even after such repeated heating and cooling the arrangement of the ferrite of the originally overheated metal was not eliminated entirely.

Where annealing in an open furnace may affect the surface of the metal, box annealing is used, the articles being placed in a box which is then placed in the furnace. Originally the boxes were made of cast iron or of steel sheets riveted together, and were often lined with refractory material. Some of the disadvantages of these boxes were their comparatively short life on account of scaling and their tendency to warp, which often made tight adherence between box and cover uncertain. Of late special alloys, usually of the type with a high chromium content, have been employed for annealing boxes. Such alloys do not scale and have less tendency to warp.

Until comparatively recently many industries viewed heat-treated products with a good deal of distrust. The early automobile manufacturers, in particular, refused to use heat-treated steel. This distrust has practically disappeared and at present enormous quantities of heat-treated steels are used in automobile, locomotive, and other constructions where great reliability combined with high strength is required. The reason for this change of attitude is probably due to two factors. In the first place, there is a clearer understanding of the mechanism of heat treatment, combined with a better knowledge of the temperatures at which it should be carried out. It is not enough, however, to know at what temperatures to treat a metal unless there is a certainty that these temperatures will be maintained in the heat-treating furnaces. This is the second factor that has led to the wide adoption of heat-treated steels in recent years. The development of special furnaces for heat treating, together with the development of methods of temperature control by pyrometers, has created a situation where properly heat-treated steel has become the rule rather than the exception, and where most of the guesswork has been taken out of the heat treating of steel. At the same time it should be clearly realized that even with pyrometric control and modern furnaces, heat treatment of steels is frankly not a job for amateurs but requires a considerable amount of skill and proper organization to give all the advantages which may be derived from it.

HARDENING

The process of hardening is based on the structural changes described above. As has been shown, steel of practically any structure can be changed to that of a solid solution or austenite by heating it through the upper critical range. When the steel is cooled down this austenite is converted first into martensite, then on further cooling into troostite, sorbite, and pearlite, depending on the temperature at which the process of cooling has been stopped and the rate of cooling. Now if the cooling is very gradual the steel will pass through all of these stages and end with a pearlitic structure which is soft and ductile, but if it is rapid, one of the intermediary stages between austenite and pearlite may be "trapped."

In the case of ordinary steel, a very rapid method of cooling called "quenching" permits trapping or stabilizing the martensitic structure, and as has been shown above, martensite is extremely hard. Hardening therefore consists of first heating a steel through the critical range and then rapidly cooling it as by quenching in a liquid capable of taking up the heat of the metal very rapidly, such as water or oil. Fig. 13 shows the changes in a 0.4 per cent carbon steel on heating and quenching.

Thus heating to a temperature *A*, under that of the lower critical range will produce no change in the original steel, which consists of pearlite (the cross-hatched circles) and ferrite (the black area). The quenching likewise will produce no change, as is illustrated by column II.

Heating to a temperature *B*, slightly over the lower critical range, will change the pearlite to the solid solution (represented by the dotted area), but without affecting the free ferrite. Quenching,

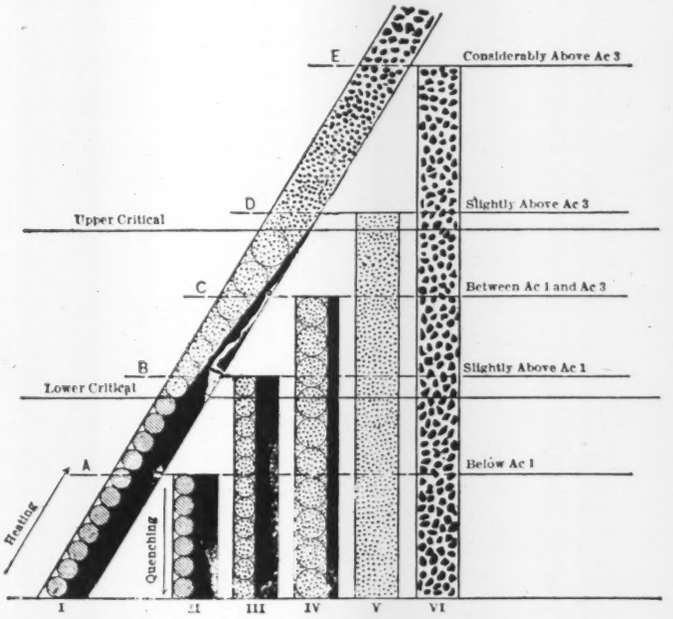

FIG. 13 CHANGES IN A 0.4 PER CENT CARBON STEEL ON HEATING AND QUENCHING

(Reproduced from Steel and Its Heat Treatment, Denison K. Bullens, by courtesy of John Wiley and Sons, New York, publishers.)

column II, will therefore produce a semi-hardened steel—since the solid solution is the "hard" constituent—with a refinement of the "ground mass" (the original pearlite) only.

Heating to a temperature *C*, between the lower and upper critical ranges, will affect a progressive absorption by the solid solution of the remaining free ferrite. Quenching, column IV, will therefore produce a "harder" steel than in case III, but nevertheless without complete refinement of the steel as a whole.

Heating to a temperature *D*, slightly over the upper critical range, if prolonged for a length of time sufficient to effect complete diffusion and equalization, will entirely refine the steel, giving it the smallest grain size possible. Quenching, column V, will retain this condition and give the maximum hardness possible.

Heating to a temperature *E*, considerably over that of the upper critical range, will tend to increase the grain size; and quenching, column VI, will retain this condition and will give a more brittle steel.

As regards heating for hardening, the general rule is that it should be slow, uniform, and thorough, and carried to the lowest temperature which will give the desired results, as heating much above the critical range will produce a coarse crystallization. There is an expression, "hardening steel on a rising temperature," which simply means that the steel is heated through the critical range and cooled suddenly as soon as it passes this range. In practice it is recommended to have the quenching temperature some 20 to 50 deg. cent. above Ac_3 in hardening eutectoid and hypereutectoid steels, and above $Ac_{3\text{-}2}$ in hardening hypoeutectoid steels. The actual quenching temperature depends, however, on the carbon content of the steel.

As regards quenching, it is very important that the piece treated should have a uniform temperature at the time of quenching. A piece may be heated to a uniform temperature in the furnace but so improperly handled that by the time it reaches the quenching bath one part of it will be hotter than another. This will produce a non-uniform hardening and may lead to warping or cracking of the piece. In order to give the metal a uniform temperature and also to make it possible to control this temperature, heat treaters resorted to the use of liquid heating baths, such as, for example, baths of molten lead and certain salts.

There are certain practical objections to the use of both lead and salt baths, but they, and particularly the salt baths, have the advantage of permitting a close control of the temperature of the bath, which can be measured with a fair degree of precision by means of a simple pyrometer, and at times estimated even without a pyrometer from a knowledge of the melting point of the salt.

THE QUENCHING BATH

A liquid is selected for a quenching bath on the basis of its ability to absorb heat from the piece at the desired rate. This latter depends in the first place upon the specific heat of the liquid, also on its conductivity and viscosity. The volatility of the liquid may be of importance because it indicates the temperature at which a vapor envelop may form around the steel that will interfere with the flow of heat from the metal to the liquid. For further data as to the behavior of the various liquids, the reader is referred to the paper, Factors in Hardening Tool Steel, by John A. Matthews and Howard J. Stagg, Trans. A.S.M.E., vol. 36, 1914, pp. 845–872. On the whole, water is the fastest-cooling medium. The most drastic cooling is obtained when a stream of water is directed on to the piece, provided the volume and pressure of the stream are sufficient to prevent the formation of a steam envelope around the piece. Dipping in a tank of water is somewhat slower than quenching by water spray. Oils are a slower-cooling medium, the various oils acting in different ways. (A list of eleven oils with their quenching factors is given in Bullens' Steel and Its Heat Treatment, p. 173.) Oil quenching is sometimes referred to as "oil tempering," while "hardening" is restricted to quenching in water only.

Brine is used only for certain particular purposes, such as hardening files, for which an extremely hard surface is required. Unless the steel has been most carefully heated and is of the proper chemical composition, quenching in brine is almost certain to crack it, particularly in the case of large sections.

Where pieces, such as large forgings, are of such a size and chemical composition that direct quenching in water may induce excessive stresses, a bath is used consisting of a tank in which a certain volume of oil is floating upon cold water. The forging heated to the proper temperature is dipped into the oil for a few seconds and then pushed down into the water. The quenching therefore proceeds in two stages and may be controlled to some extent, while the rapidity of cooling in water is somewhat delayed by the film of oil which forms on the surface of the steel. When small tools are treated in this way they are simply plunged through the oil into the water, the thickness of the oil layer regulating the relative importance of the two stages of cooling.

It is very important to maintain the quenching bath at the proper temperature, as the rapidity of quenching depends on the temperature of the bath. In the case of water, 50 deg. fahr. difference of temperature make a big difference in quenching results. Where a bath is used continuously, provision has to be made to cool it.

One of the greatest dangers in hardening and subsequent quenching is the possibility of cracking and warping the piece being treated. This is due to two factors. In the first place, all metals expand on heating and contract on cooling, and hence will rapidly contract in quenching. However, this is not the only factor tending to produce stresses. In the discussion of the critical ranges it was indicated that the formation of austenite takes place with a decrease in volume, while the degeneration of the austenite to martensite on cooling through the same range is accompanied by an increase in volume, and there is a second increase in volume as martensite breaks down into pearlite. If a large piece of steel is quenched rapidly the outer section will be held in the hardened condition, say, martensite, while the interior, being cooled less rapidly, will pass to a lower stage, such as pearlite, and will there-

fore increase in volume, the result being a stress from the inside against the outer shell. This stress may be extremely high; for example, heavy locomotive-axle forgings have been known to burst open with a report like a piston shot upon the removal from the oil hardening bath.

In order to reduce these internal stresses heavy forgings of large diameters, axles, shafts, etc., are drilled or hollow-bored so that the quenching solution can remove the heat from both the inner and outer part of the axles at the same time and the internal pressure may be relieved and also distributed between two surfaces instead of one. Hollow-bored axles should be quenched vertically whenever possible, and provision should be made for a constant flow of the quenching liquid through the bore.

Warping may be due either to the same causes that produce cracking or to unequal contraction and expansion of the various parts of the piece because of incorrect heating or improper quenching.

At times (chiefly with low- and medium-carbon steels) double quenching is used in order to raise the elastic limit and tensile strength without diminishing the ductility. This is usually done by first quenching from a temperature 100 to 200 deg. above the critical range, then reheating to just enough over the critical range to obtain the degree of hardness required, and quenching again.

ANNEALING OF COLD-WORKED METAL

As explained in the chapter on the Crystalline Structure of Metal, the present theory is that such metals as steel consist of crystals having certain more or less definite shapes, the space between them being filled by an amorphous material which may be called the "intercrystalline cement." It is further presumed that when metals are subjected to deformation below the annealing temperature there occurs a slip or shear of mobile layers at the internal surfaces. Furthermore, these later are supposed to retain their mobility for only a very brief period. Then they solidify in a vitreous (glasslike), amorphous state and this vitreous mass is hard and to a certain extent brittle, like glass. The result is a hardening and embrittlement of the metal.

Now it has been found that metals which have been hardened by cold work can have this hardness removed by being heated to a suitable temperature. It would appear that heating restores the crystalline state of the metal which has been made amorphous by the cold work. Not only this, but it would appear that where during the cold work grains of metal have been deformed, the heating leads to the distorted grain structure being replaced by new grains. It also appears that these new grains are essentially of such a character that their diameters are approximately the same in all directions (such grains are called "equiaxed"). This process of restoring the softness and ductility of cold-worked metal is also called annealing and the process occurring in the metal is referred to as "recrystallization." The recrystallization temperatures differ from the temperatures used in annealing to remove hardness produced by excessively quick chilling, and, for example, for iron are of the order of a minimum of 450 deg. cent., although usually a higher temperature is employed. Excessively high temperature will produce grains which are too large. For further information on cold work and the effect of annealing, see references below and in Chapter II, MECHANICAL ENGINEERING, June, 1925, p. 484.

TEMPERING

The result of heating a piece of steel through the upper critical range and then quenching it in water is that the steel becomes hard. This is due, as stated above, to the fact that the degeneration of austenite has been arrested at the martensitic stage. Unfortunately, however, such hardness is often accompanied by brittleness and also by what are known as hardening strains, which latter may be so high with certain types of steel as to cause the piece to shatter, and which always constitute a source of weakness in the material.

As a rule, as for example in tool steels, it is desirable to have only a reasonable degree of hardness accompanied by high mechanical strength, rather than a mechanically weak but extremely hard structure. To obtain the former, heat is applied in a certain manner, and this removes more or less the hardening stresses and converts to the desired degree the hard and brittle martensitic structure into a softer and tougher troostitic or sorbitic structure. Such an application of heat as will result in the establishment of a troostitic structure is called "tempering." Troostite begins to form at about 400 deg. fahr. or a little lower, and as the tempering temperature is increased the amount of troostite increases, until at about 750 deg. it begins to change into sorbite.

The old blacksmith, who in his way was an adept at tempering, had to work without thermometers or pyrometers. He knew, however, that if a piece of hardened steel was cleaned with emery cloth or a fine file and then heated slowly in the air, characteristic "temper colors" would appear on the cleaned surface, beginning with a faint yellow at about 420 deg. fahr., and gradually passing through brown and purple into a greenish blue. When the desired color was reached, the blacksmith used to quench the piece to stop any further rise of temperature, or as it was called, "to set the grain." This is, however, a very crude process, as the color method is at best only a rough way to judge of the temperature, and as it indicates little beyond the surface temperature—and even at that does not insure that the temperature over the entire surface is uniform. The quenching from a given color is also apt to make trouble, as too much reliance has to be placed on the personal equation of the operator.

Modern tempering is therefore done by means of so-called liquid baths, usually oil. The bath is maintained at the proper temperature determined by a thermometer, and the pieces are immersed in it, and kept until thoroughly and uniformly "soaked through with heat." If the piece is kept in the bath longer than is absolutely necessary, no harm can result as the piece cannot be overheated. It is desirable to immerse the steel into the bath when the latter is some 200 to 300 deg. below the highest temperature employed in the tempering operation, and to bring the steel tempered and the bath to the required temperature together. As a general rule, when liquid baths are employed for tempering, quenching is unnecessary.

TOUGHENING

As has been stated above, heating to about 400 deg. fahr. or a little below it, converts the martensite into the softer and stronger troostite. A reheating (or, as it is sometimes called, "drawing") to a still higher temperature, say, 750 deg. fahr. (medium forging and higher-carbon steels), changes the troostite into sorbite (cp. May issue, p. 344), which latter is endowed with great tenacity and high elastic limit. Because of these properties sorbitic steels are called "toughened steels," and the process of producing them referred to as "toughening." This is carried out by reheating the steel (usually of the medium forging and higher-carbon grades) to some temperature above 750 deg. fahr. but below 1250 deg., as at this latter temperature sorbite is converted into pearlite. The higher the toughening temperature, the lower the tensile strength and elastic limit, and the greater the ductility and dynamic endurance, which simply means that the steel approaches more nearly the properties of pearlitic steel. The effects of temperature on ductility are more complicated, and are expressed by Denison K. Bullens (p. 203) as follows: "Through the sorbitic stage at least, each increment of decrease in tensile strength and elastic limit is associated with, and counterbalanced by, an increase in the reduction of area and elongation. This combination of static strength and ductility is further almost directly proportional to the toughening temperature."

It may be stated in conclusion that we are unquestionably only at the beginning of the proper comprehension of the mechanism of heat treatment and of the advantages that may be derived therefrom. It is stated on good authority that at the works of one of the largest automobile manufacturers in the country intensive work is being done to determine whether alloy steels for certain parts might not be replaced, without impairing the strength of the parts, by carbon steels, provided these latter were given as careful heat treatment as alloy steels usually get. If this can be done, new and vast possibilities open up before the mechanical and metallurgical engineer.

REFERENCES ON THE EFFECT OF COLD WORK ON STEEL

Hoyt, Metallography—Metals and Common Alloys, 1921, p. 212 et seq.
Zay Jeffries and Robt. S. Archer, The Science of Metals, 1924, pp. 48–66.

Corrosion of Alpha-Beta Brass as Affected by Grain Size

By ROBERT J. ANDERSON[1] AND SAMUEL H. BROOKS[2]

THIS paper gives the results of a series of tests made on the accelerated electrolytic corrosion of the brass 66: 33: 1 copper-zinc-tin. In the tests examination was made of the effect of grain size in the range 0.01 mm. diameter to 0.10 mm. on the corrosion loss in six different corroding media.

In a previous paper by one of the authors and G. M. Enos,[3] it was shown that varying grain size (0.01 mm. to 0.10 mm.) in the case of the alpha brass 70: 29: 1 copper-zinc-tin had little or no effect upon the corrosion rate in six different solutions. The work described in the present paper is in amplification of that previously reported and in confirmation thereof. The results obtained in both these investigations are not in harmony with the amorphous-cement theory, since, if the amorphous phase is more soluble than the crystalline phase (as it is stated to be), fine-grained metal would corrode more rapidly than coarse-grained. This would follow because there would be present a greater amount of the amorphous phase of a metal when fine grained than when coarse grained.

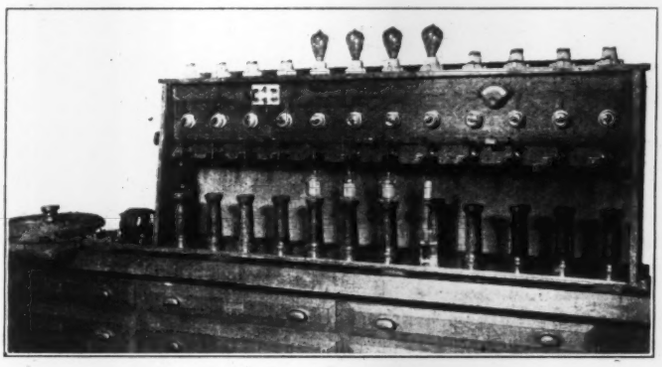

FIG. 1 SET-UP OF ELECTROLYTIC APPARATUS FOR MAKING ACCELERATED ELECTROLYTIC TESTS

The results reported here should be of interest to makers and users of condenser tubes.

MATERIAL USED FOR TESTING

The material used in these tests was alpha-beta brass in the form of condenser tubing, furnished through the courtesy of a brass manufacturer. The tubes were $^3/_4$ in. in outside diameter, 0.05 in. in wall thickness, and 18 in. long, and varied in grain size from 0.01 mm. in diameter to 0.10 mm., increasing by increments of 0.01 mm. There were thus ten grain sizes. The average chemical composition of the lot of tubes was—

	Per cent
Copper	66.274
Lead	0.014
Iron	0.040
Tin	1.205
Zinc (by difference)	32.467

The tubes were made by the ordinary drawing practice employed in brass mills, and the different grain sizes were produced in the samples by particular time-temperature anneals of hard-drawn tubing. As would be expected from the copper-zinc equilibrium diagram (and taking into account Guillet's coefficient of equivalence for tin: zinc), this brass is an alpha-beta brass, the amount of free beta being rather small.

METHOD OF TESTING

The different tube samples were tested for corrosion loss in six electrolytes: viz., (1) acid mine water (from the Edna No. 2 mine of the Hillman Coal and Coke Co., at Wendel, Westmoreland county, Pa.) containing 1078 p.p.m. total acidity, expressed in terms of H_2SO_4; (2) dilute sulphuric acid in aqueous solution (15,760 p.p.m. H_2SO_4); (3) sea water, 4 per cent sea salt by weight in aqueous solution; (4) aqueous sodium chloride solution, 8 per cent NaCl by weight; (5) aqueous sodium hydroxide solution, 1 per cent NaOH by weight; and (6) tap water, containing 8 p.p.m. of calcium carbonate.

The corrosion test employed was the accelerated electrolytic corrosion test devised by one of the authors, G. M. Enos, and J. R. Adams, which has been described in published papers.[1,2] In this test the material to be tested is made the anode in the corroding medium (an electrolyte), and platinum wire is used as the cathode. A small current density is imposed through suitable connections and properly regulated, and the anode is rotated in the electrolyte. After a suitable time period of exposure to these corroding conditions the sample is removed, washed, dried, and weighed, and the actual loss in weight determined. The corrosion loss may be expressed conveniently in milligrams per square centimeter per 24 hours, and for comparative purposes it is useful to take account of variations in the current density and reduce the losses to a common basis by dividing the losses by the particular current densities imposed, for definite time periods of exposure.

Fig. 1 shows the electrolytic apparatus developed by the authors in the U. S. Bureau of Mines for use in making accelerated electrolytic tests, and Fig. 2 the wiring diagram for the apparatus.

In the tests described here on the alpha-beta brass tubes, certain improvements have been adopted in manipulative methods over those previously employed, and these improvements are indicated below in discussing details of the testing method. In general,

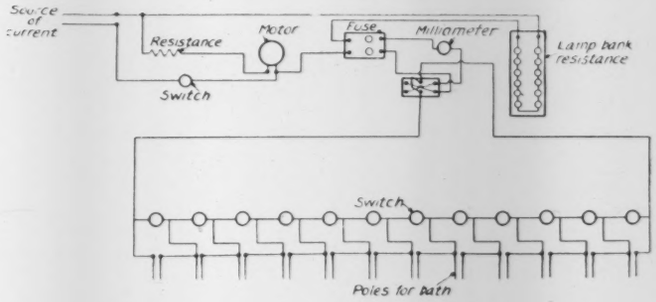

FIG. 2 WIRING DIAGRAM OF THE ELECTROLYTIC APPARATUS SHOWN IN FIG. 1

however, the method of test was similar to that previously used by one of the authors and G. M. Enos[3] in tests on 70: 29: 1 copper-zinc-tin alloy tubes.

In the present tests the speed of rotation of the test pieces was held constant at 140 r.p.m. and controlled by a rheostat in series with a constant-speed motor. The electrolytes were contained in 500-cc. glass jars, and the temperature was 20 deg. cent. ±. Twelve cells were connected in series and operated simultaneously. These cells were connected in series with a lamp-bank resistor and a very sensitive milliammeter which could be read to 0.001 ampere. With this arrangement the current density could be measured and controlled very accurately, so that, as far as was possible, a constant current density was maintained throughout the runs.

The tube samples as received were cut into 2-in. lengths, and to

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[2] Metallurgical Chemist, Pittsburgh, Pa.

[3] R. J. Anderson and G. M. Enos, Corrosion of Brass as Affected by Grain Size. Trans. A.I.M.E., vol. 70 (1924), p. 391.

[1] R. J. Anderson, G. M. Enos, and J. R. Adams, Accelerated Corrosion Testing of Metals and Alloys in Acid Mine Water. Bull. 6, Coal-Mining Investigations Series, Carnegie Inst. of Technology, Pittsburgh, Pa., 1923 64 pp.

[2] R. J. Anderson and G. M. Enos, An Accelerated Electrolytic Corrosion Test. Proc. A.S.T.M., vol. 24 (1924), p. 735.

[3] R. J. Anderson and G. M. Enos, Corrosion of Brass as Affected by Grain Size. Trans. A.I.M.E., vol. 70 (1924), p. 391.

one end of each of these a 1-in. length of copper wire was soldered so that the samples could be fastened into the chucks of the electrolytic apparatus.

In previous experiments[1] with tube-shaped samples it was found rather difficult to make accurate surface measurements of areas exposed to the action of the corroding medium, since both the inside and outside surfaces of the tubes were exposed and the water line was rather irregular owing to swirling and splashing by the electrolyte. In order to minimize errors from this source, the method was adopted of coating the tubes in such a way as to leave only a definite surface area exposed. The following treatment was adopted: The desired depth of immersion to give a particular area for exposure was calculated, and the corresponding length was laid off along the tube, a light level cut being made with a lathe tool to fix the point. The top portion of the tube was then immersed to this level cut in a liquid solution of beeswax and paraffin, which, upon solidification, became hard and formed a protective coating on both inside and outside surfaces of the upper portion of the tube. The inner lower wall surface was cut off by inserting a cork stopper in the bottom, and another cork stopper was placed in the top of the tube so as to prevent the electrolyte from splashing into the inside. By this method the entire set of samples could be prepared beforehand and the surface area maintained practically constant for any required number of test pieces. Fig. 3 shows a tube sample prepared in the above-described fashion, after being corroded. In the present tests the surface area employed for exposure was 23.50 sq. cm., using a depth of immersion of 3.81 cm. (1.5 in.). The actual surface exposed when the sample is prepared as described includes the external surface between the coating and the bottom of the tube, plus the small annular ring at the bottom formed by the cross-section cut through the wall.

In the tests the current imposed was 0.042 ampere, which corresponded to a current density of 0.179 ampere per square decimeter of surface area exposed. This current density applies to the first five solutions but not to the tap water. Owing to the poor electrical conductivity of the tap water, the maximum current density obtainable was 0.03 ampere per sq. dm. The various test samples were run for 8-hr. periods in the electrolytic apparatus, and, after the completion of the runs, were scrubbed with a stiff bristle brush to remove any loose scale, dried, and weighed. Drying was done in a desiccator in order to avoid softening the protective coatings. The weight losses were determined by difference.

TABLE 1 ACCELERATED ELECTROLYTIC CORROSION LOSSES OF 66: 33: 1 AND 70: 29: 1 COPPER-ZINC-TIN BRASS TUBES COMPARED

Electrolyte	Loss[1] in mg. per sq. cm. per 24 hr. 66: 33: 1 Cu-Zn-Sn alloy	70: 29: 1 Cu-Zn-Sn alloy
Acid mine water	65.5	44.6
Dilute sulphuric acid	56.1	38.2
Sea water	77.4	49.6
Sodium chloride solution	79.8	50.7
Sodium hydroxide solution	22.6	5.80
Tap water	3.40	2.58

[1] Average loss for tubes of 0.01 to 0.10 mm. diameter grain size.

TABLE 2 EFFECT OF GRAIN SIZE ON CORROSION LOSS OF ALPHA-BETA BRASS TUBING IN SIX ELECTROLYTES (ACCELERATED ELECTROLYTIC TEST)

Grain size, diam. in mm.	Weight loss in grams divided by current density: 8 per cent salt solution (NaCl)	4 per cent sea-salt solution	Mine water, Edna No. 2	Dilute sulphuric acid solution	1 per cent sodium hydroxide solution	Tap water-$CaCO_3$ (8 p.p.m.)
0.011	3.46	3.38	2.90	2.46	0.92	0.87
0.020	3.37	3.35	2.78	2.49	1.00	0.87
0.031	3.44	3.38	2.87	2.46	0.97	0.92
0.038	3.43	3.38	2.86	2.50	1.00	0.82
0.050	3.41	3.33	2.84	2.45	1.00	0.93
0.058	3.44	3.29	2.89	2.46	0.97	1.08
0.071	3.41	3.39	3.02	2.47	0.98	0.88
0.083	3.44	3.39	2.63	2.44	0.99	0.88
0.090	3.43	3.38	2.86	2.44	0.98	0.94
0.100	3.45	3.36	2.82	2.47	0.97	0.92

[1] R. J. Anderson and G. M. Enos, op. cit.

FIG. 3 TUBE SAMPLE PREPARED FOR CORROSION TEST
(Coating at top portion: corks in top and bottom.)

RESULTS OF THE TESTS

Table 1 gives figures for the average corrosion losses of the 66: 33:1 copper-zinc-tin brass tubes in the six different electrolytes, and the corresponding losses for the 70: 29: 1 copper-zinc-tin tubes obtained from a previous investigation are included for comparison. These average losses were obtained by taking means of the weight losses for tubes of ten grain sizes from 0.01 to 0.10 mm. in each case. As might have been expected, the corrosion losses of the 66:33:1 copper-zinc-tin tubes in the various solutions were substantially greater than of the 70: 29: 1 copper-zinc-tin tubes in corresponding solutions, since a duplex alloy of a particular type would normally be expected to corrode more rapidly than a solid-solution alloy of the same type.

The average values of the weight losses divided by the current density for duplicate runs on the 66: 33: 1 copper-zinc-tin tubes are given in Table 2 and plotted in the graphs of Fig. 4. The abscissas represent the diameter of grains in millimeters, and the ordinates represent the values of the ratio of the various weight losses divided by the current density, i.e., the values are reduced to a unit current-density basis. The graphs of Fig. 4 are practically straight and parallel lines, and they indicate, as do the actual loss data,

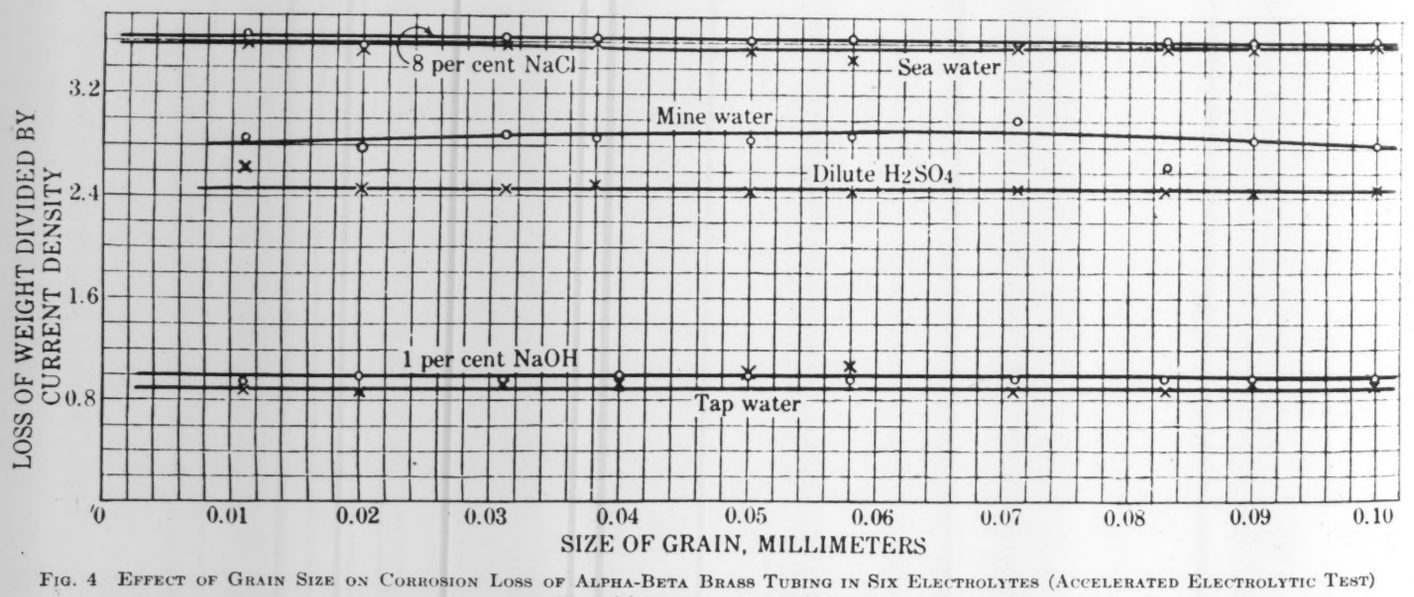

FIG. 4 EFFECT OF GRAIN SIZE ON CORROSION LOSS OF ALPHA-BETA BRASS TUBING IN SIX ELECTROLYTES (ACCELERATED ELECTROLYTIC TEST)
(Plotted from values given in Table 2.)

that grain size within the limits tested has no effect on the rate of corrosion. For each of the solutions the weight losses for the tubes of different grain size were substantially the same, i.e., grain size had no effect on the corrosion loss.

In the previous paper by one of the authors and G. M. Enos[1] on the effect of grain size on the corrosion rate of 70: 29: 1 copper-zinc-tin brass tubes, graphs corresponding to those in Fig. 4 of the present paper were plotted and showed slight slopes and curvatures. On the basis of the present data it is believed that these curvatures are discrepancies which may have been due to the less accurate method previously employed for measuring the total areas exposed to the corroding media. Because of the uneven water line in the previous tests it was difficult to measure the exact height of the corroded portion, and hence the calculation of the area exposed was open to error. With tube shapes it is especially difficult to determine the height of the corroded portion on the inside surface, and this surface may be conveniently blocked off with a cork stopper. The source of error owing to uneven water line was eliminated in the present tests by the new method employed for preparing the samples as described above.

SUMMARY AND CONCLUSIONS

1 Tests have been carried out on the accelerated electrolytic corrosion of brass condenser-tube samples of the nominal composition 66: 33: 1 copper-zinc-tin in six electrolytes; viz., (1) acid mine water; (2) dilute sulphuric acid; (3) sea water: (4) sodium chloride solution; (5) sodium hydroxide solution; and (6) tap water. The tube samples varied in grain size from 0.01 to 0.10 mm. in diameter by increments of 0.01 mm., there being ten grain sizes.

2 The accelerated electrolytic-corrosion test, wherein the sample for test is made the anode in the corroding solution, was used.

3 The effect of grain size on the corrosion rate was found to be nil.

4 The average corrosion losses for the 66: 33: 1 copper-zinc-tin tube samples in the different electrolytes were found to be as follows: (1) in acid mine water, 65.5 mg. per sq. cm. per 24 hr.; (2) in dilute sulphuric acid, 56.1 mg.; (3) in sea water, 77.4 mg.; (4) in sodium chloride solution, 79.8 mg.; (5) in sodium hydroxide solution, 22.6 mg.; and (6) in tap water, 3.40 mg. per sq. cm. per 24 hr.

5 The foregoing values for the 66: 33: 1 copper-zinc-tin tubes may be compared with the following values for 70: 29: 1 copper-zinc-tin tubes in the same solutions: viz., (1) in acid mine water, 44.6 mg. per sq. cm. per 24 hr.; (2) in dilute sulphuric acid, 38.2 mg.; (3) in sea water, 49.6 mg.; (4) in sodium chloride solution, 50.7 mg.; (5) in sodium hydroxide solution, 5.80 mg.; and (6) in tap water, 2.58 mg. per sq. cm. per 24 hr.

6 The alpha-beta brass (nominal composition 66: 33: 1 copper-zinc-tin) corroded more in all the solutions than the alpha brass (nominal composition 70: 29: 1 copper-zinc-tin), as would be expected, since a duplex alloy of a given type would normally be expected to corrode more than a solid-solution alloy of the same type.

7 The results of this investigation and of another previously reported indicate that grain size has no important practical effect on the corrosion of condenser tubes and can be ignored, provided of course that the grain size lies within nominal limits such as are ordinarily understood for condenser tubes.

An Oil Separator for Purifying Ballast Water Discharged from Ship Fuel-Oil Tanks

By W. J. BARNES,[2] ANNAPOLIS, MD.

The increased use of fuel oil on shipboard has led to harbor pollution. Vessels are now obliged to eliminate oil from the discharge water, and the author describes a gravity separator that has been found very effective in achieving such elimination, as indicated by a complete test.

THE increased use of fuel oil on shipboard has resulted in pollution of harbor waters, with the attendant destruction of fish and material increase in the fire hazard of harbor property. This problem has become so serious that the last Congress passed a law prohibiting the discharge of oil or water containing oil into coastal waters of the United States and territories. Thus a vessel approaching these shores must pump ballast water from oil tanks some distance at sea. This procedure means loss of time if the ship lays to outside of the limits to pump tanks; or if pumping is started some distance at sea the stability of the boat is materially decreased, which from an operating standpoint is inconvenient and may be a dangerous procedure in heavy weather. Various methods of eliminating the oil from the discharge water have been suggested, one of the most interesting of which is the "Rocket" oil separator, which was recently tested at the U. S. Naval Engineering Experiment Station.

PRINCIPLE AND OPERATION OF THE SEPARATOR

The separator tested had a designed capacity of 50 long tons or 13,450 gal. of liquid per hour, and was manufactured in England under direction of the inventor, H. M. Alexander. It is of the gravity type and depends entirely for successful operation upon the difference in density of oil and water.

In actual construction the separator has four distinct stages in which separation takes place, as shown on the sectional elevation, Fig. 1. The mixture of oil and water is introduced into the feed box through the inlet nozzle marked *A*, and after passing over the weir and through the expanded-metal screen, it flows through the pipe *B-C*, passes the deflector *D*, and enters the first-stage compartment, where the major portion of the separation takes place. The oil rises to the top of the cone and when a sufficient head is built up, it overflows the circular weir into the annular oil-seal section, and passing through the oil-discharge pipe, is conducted from the separator.

The water from the first stage, which still contains an appreciable amount of oil, passes into the second-stage compartment from the bottom of the first stage and through four 4-in. risers, the entrances of which are near the bottom of the first-stage compartment. Deflector plates are provided at the outlet of each riser. Further separation takes place in this compartment, the oil rising to the top and passing through the 2-in. pipe nozzles into the oil-seal compartment and thence out of the separator. The water passes out of the bottom of the second compartment through an annular space between the first-stage and the second-stage compartments, and thence over a circular weir into the third-stage compartment. This compartment is filled with broken glazed pottery. The water passes downward through this compartment and out at the bottom; then, rising through another annular space and passing over another weir, it enters the top of the fourth-stage compartment which is also filled with crockery. The water passes down through this compartment and enters the 7-in. water-outlet pipe which is located at the bottom of the casing. It then rises to the bottom of the discharge chamber of the feed box and, falling over another weir, enters the outboard delivery line of the separator.

The flow of the water and oil through the separator is entirely by gravity. The crest of the outlet weir is $6^3/_4$ in. below that of the inlet, the head thus provided being sufficient to maintain a steady, even flow without the necessity of any manual adjustment or regulation.

The construction of the feed box permits any entrained air in

[1] R. J. Anderson and G. M. Enos, op. cit.

[2] Associate Mechanical Engineer, U. S. Naval Engineering Experiment Station.

Presented at a meeting of the Baltimore Local Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Annapolis, Md., November 1, 1924.

the mixture to pass off before entering the first stage. Any air or vapors that are thrown off during further separation are carried away through the air vents provided as shown.

In the tops of the first- and second-stage compartments are located two heating coils controlled by suitable valves, Nos. 1, 2, and 3. Valves 4 and 5 control the steam supply to the scrubber lines in compartments 3 and 4, respectively. Condensed steam from the coils is discharged through pipes to a header and thence through a steam trap to the hot well.

Under normal operating conditions, steam will be supplied to the first heating coil in the first-stage compartment only, but under winter conditions it may be necessary to supply additional steam to the second coil in the first stage and to the coil in the second stage in order to reduce the viscosity of the oil and effect further separation.

When the separator is in operation, the small quantity of oil remaining in the water after leaving the second stage is further reduced by adhesion to the crockery in the third and fourth stages, the particles of oil adhering tenaciously to the glazed surfaces of the pottery while the water passes through.

After the separator has been in operation for a considerable length of time, the pottery filters in the third and fourth stages are cleansed by "scrubbing" with steam. To accomplish this cleansing the discharge valve in the water-outlet line is closed and sufficient water added through the inlet line to raise the water level within the separator above the "scum gutter" located between the third- and fourth-stage compartments. The water supply is then cut off and steam admitted through valves 4 and 5. The steam passes through the pipe coils at the bottom of the compartments and out through small holes drilled in these pipes. The steam and hot water seem to have a scouring action which breaks loose the oil from the surface of pottery and causes it to rise to the surface.

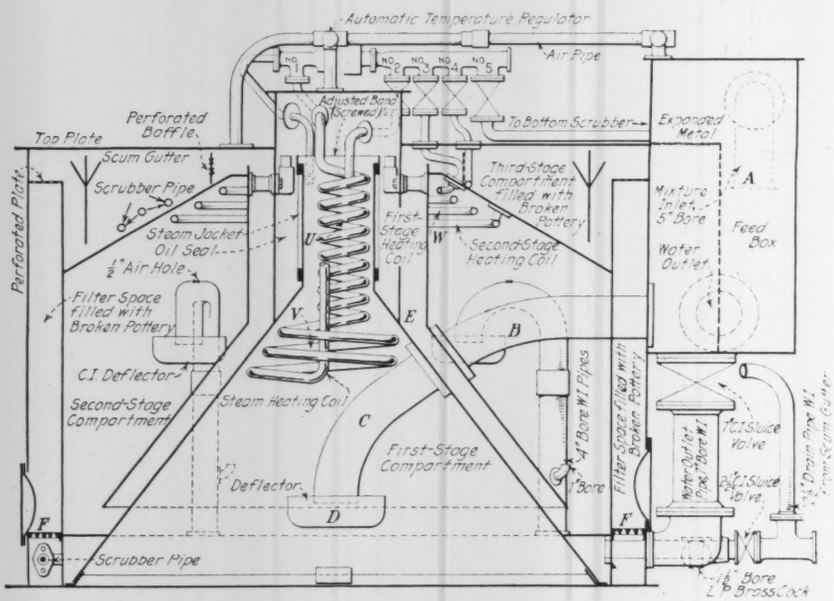

FIG. 1 DIAGRAMMATIC ARRANGEMENT OF "ROCKET" OIL SEPARATOR

After the scrubbing action is completed, the valve in the drain line from the scum gutter is opened and the accumulated oil is drained, either into the second-stage compartment for further separation, or to the suction line of the pump for repassage through the separator. Water may be added to the separator to maintain the oil and water level above the scum gutter until the surface is thoroughly clean, but it is generally desirable to keep a thin film of oil over the surface of the water in the separator as this film seems to have an affinity for minute particles of oil which otherwise might be carried further into the separator.

DESCRIPTION OF TEST

The general arrangement of the separator for the test is shown in Fig. 2. Water from the Severn River was supplied to the separator through a 6-in. line by a centrifugal pump. The oil injection nozzle was located at one outlet of a tee in the supply line. Bunker A fuel oil was used during the test. The oil was run by gravity from the two large oil storage tanks to the suction oil storage tank, from which it was drawn by the injection oil pump and passed through the oil meter into the water line. The oil discharged from the separator ran by gravity into the separated-oil storage tank from which it was raised by the second pump to the oil storage tanks.

In conducting the test, oil was introduced into the separator at

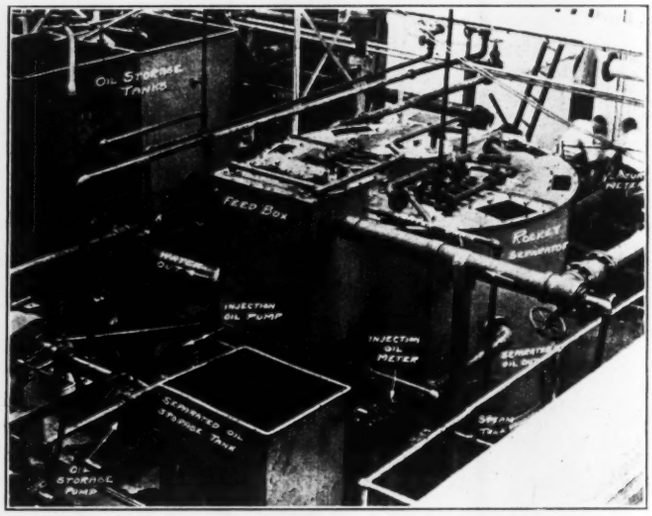

FIG. 2 SET-UP OF SEPARATOR FOR TEST

three different rates of flow, namely, 5, 25, and 50 long tons per hour. Runs were made at each of the three rates of flow with an oil content of appproximately 2, 5, and 10 per cent. An overload run with 5 per cent oil content was also made. The above runs were made with a $1^1/_2$-in. by $^3/_4$-in. reducing coupling screwed on the end of the $1^1/_2$-in. oil supply line. Runs were also made with full $1^1/_2$-in. pipe opening and with a nozzle composed of $1^1/_2$-in. pipe capped at the end and helically drilled with sixty $^1/_4$-in.-diameter holes. Two runs were also made to determine the efficiency of separation in the first two gravity stages as compared with the complete separation obtained with the entire separator. The data observed covered rate of water injection, rate of oil injection, temperature of mixture in, temperature of outlet oil, first stage, and temperature of water out. Samples of injection oil, separated oil, and discharge water were taken on all runs, and on the last two runs samples of water at the end of the second stage were also taken. The oil samples were analyzed for water content and the water samples for oil content.

The negligible amount of oil in the discharged water is clearly shown by the analyses of the samples taken. It was found that this oil would eventually rise to the surface of a sample of the discharge water if allowed to stand for a few minutes, but this oil was practically invisible unless the surface of the water was viewed by reflected light, no connected oil film being formed.

The separated oil, when analyzed, was found to have a noticeable entrained-water content which gradually increased as the test proceeded. This water content was a result of continued recirculation of the injection oil through the separator. It may be noted, however, that in general the increase in water content in the oil for a single passage through the separator was not over 4 per cent. Run 1 was of a preliminary nature and, as regulation was not entirely satisfactory, the run was checked by run 10. The water in the discharge oil was generally in a very finely divided state, possibly existing as an emulsion, and very little would settle out of the oil samples. When the separator was operated at the overload

rate of 60 tons per hour, some free water was thrown out with the discharge oil, as was indicated by the increase in water content of 8 per cent in run 12. Above this rate of flow a considerable quantity of water passed out with the separated oil.

It is interesting to note that even at rates of flow in excess of the designed capacity of the separator, the discharge water was, for all practical purposes, clean. The slight increase in oil content of the discharge water appeared as occasional extremely small globules which, when allowed to stand, would gradually rise to the surface of the sample and would barely form a connected oil film.

TABLE 1 SUMMARY OF RESULTS OF TEST OF "ROCKET" OIL SEPARATOR

Run Number	Rate of flow of mixture entering separator, long tons per hr.	Percentage of oil in mixture	Parts of oil per million parts of discharge water	Oil discharged with separated water, lb. per hr.	Parts of oil per million parts of water in second stage	Remarks
1	50.67	1.20	4	0.45	..	With ¾-in. plain nozzle
2	50.75	4.51	11	1.19	..	
3	52.86	10.10	32	3.41	..	
4	26.55	9.45	9	0.48	..	
5	25.33	5.09	6	0.32	..	
6	25.60	1.91	5	0.28	..	
7	5.37	9.31	5	0.05	..	
8	5.54	5.60	6	0.07	..	
9	8.44	2.25	8	0.08	..	
10	50.29	1.99	5	0.55	..	Check run for run No. 1
11	50.46	4.74	4	0.43	..	1½-in. pipe opening for nozzle
12	63.18	4.99	6	0.81	..	Overload run
13	50.50	4.83	23	2.48	..	Nozzle with ¼-in. holes
14	5.94	5.05	6	0.08	9	For data on second stage
15	46.09	4.79	6	0.59	11	For data on second stage

The analysis of the water from the second gravity stage, runs 14 and 15, shows the effectiveness of the gravity separation as well as the ability of the filters to remove the oil which still remains in the water after passing the first two stages.

No effort was made to measure the steam consumption, as very little was used. An estimate of the steam consumption for typical full-load conditions as obtained in run 2 is as follows:

Rate of flow of water through separator	48.46 tons per hr.
Rate of oil flow through separator	2.29 tons per hr.
Temperature rise of water	1.3 deg. fahr.
Temperature of separated oil	91.3 deg. fahr.
Temperature rise of oil	13.4 deg. fahr.
Heat absorbed by water based on 1 B.t.u. per lb. per deg. rise	141,115.5 B.t.u.
Heat absorbed by oil based on specific heat of 0.398	27,357.2 B.t.u.
Total heat absorbed exclusive of radiation losses	168,472.7 B.t.u.
Steam consumption at 15 lb. gage, latent heat of 945 B.t.u. per lb.	178.3 lb. per hr.

During the test many of the runs were made with steam on the heating coils only a portion of the time. The scrubbers need steam only at occasional intervals when it becomes necessary to clean the filters. The scrubbing action of the steam seemed to be effective as was evinced by the amount of scum which rose from the filters.

CONCLUSIONS

From data and observations taken during the test, the following conclusions may be drawn:

a The separator is very effective in operation within and slightly in excess of its rated capacity.

b The steam consumption is low, and in some cases heating may be practically dispensed with. A thermostat-controlled valve would be desirable in place of valve 1, which, during the test, was manually operated.

c The separator functions at any rate of flow within its rated capacity with no regulation or attention other than that required by the heaters and scrubbers.

d The effectiveness of separation is dependent to some extent upon the intimacy of the mechanical mixture of oil and water.

e The separator appears to function with mixtures of oil and water where a slight emulsification has occurred, emulsified oil being separated out with other oil.

Design of Air-Cooled Cylinders

THE data given in this article refer particularly to aircraft engines. The design starts with the determination of the displacement for the cylinder and selection of bore and stroke, these depending on the type and arrangement of engines, normal speed of crankshaft rotation, power output required, and certain other factors. It is hardly desirable to secure high power at the expense of fuel economy. Fortunately, however, conditions favorable to a high power output tend to result also in good fuel economy.

The power output for a given size and speed is controlled largely by combustion-chamber design, sizes of valves, size and shape of ports, and cooling of the cylinder. The author recommends the adoption of a combustion chamber approaching as nearly as possible spherical shape, which means that the cylinder head must be approximately hemispherical and the valves and ports must be inclined to the horizontal.

As regards valve design, experience has shown that in order to develop maximum power it is necessary to have 1 sq. in. of intake-valve opening for each 32 cu. in. of piston displacement. It is desirable to have an equivalent amount of exhaust-valve opening, but where the space for the valves is restricted, the exhaust-valve size may be reduced to a point where 1 sq. in. of valve opening serves as high as 40 cu. in. of piston displacement. Experiments have shown that it is possible to lift the valves to a height as great as one-fourth of their diameter and still count on the full area of the valve opening, provided there is sufficient space between the edge of the valve and side of the combustion chamber so that the gas flow will not be restricted at this point. The figures given for valve area apply to the present tendency in air-cooled-engine design, where the engines are run at speeds not exceeding 2000 r.p.m. For the very high-speed engines, 1 sq. in. of valve opening for every 25 cu. in. of piston displacement is desirable.

One of the most important considerations in securing maximum power output is the size and shape of the intake and exhaust ports. The internal shape of the ports must be such as to offer the minimum resistance to the flow of the gases in and out of the cylinders, while their external shape must be such as to accommodate reasonable forms of intake and exhaust manifolds, and to offer the least possible interference to the flow of the cooling air around the cylinder head. In order to offer the least possible restriction to gas flow, the passages within the ports must have easy bends with plenty of area at the bends, especially around the valve-guide bosses. Rapid changes of section must be avoided, and the area of any section of the passage must always be as great as, or greater than, the clear area of the valve opening. The external shape of the port will be considered under the next heading.

As regards cooling, the most difficult problem is that of cooling the exhaust valve, which is largely a question of providing ample area for the transfer of heat to the valve seat and valve guide and then providing for the best possible air cooling of these ports.

Proper cooling of the exhaust port depends primarily on its position with relation to the stream of cooling air. It is essential that the port be exposed directly to this air stream without interference from the intake port, manifolds, or exhaust pipes. The exhaust port must therefore be placed either directly in front, or at one side of the intake port, considering the "front" of the cylinder as the side against which the air stream is directed. It is usually desirable to face the port opening directly back, so that the exhaust pipe will not interfere with the free flow of cooling air to the port, valve seat, and cylinder head. In a V-type engine the cooling air is usually taken in through the front of the V and passed out between the cylinders. This necessitates placing the exhaust port in a position toward the inside of the V in order that cooling air may strike it as directly as possible. In this case it is usually not possible to face the port away from the air stream, and in order to avoid interference with the air stream the exhaust pipe is turned abrupting upward from the port opening and led out through the top of the cowling. The ports must be arranged with ample air space between them, so that the cooling air passes directly over the hot portion of the combustion chamber which is always present between the valve seats. It is generally advisable to place the spark-plug bosses in such a position that the spark plugs are directly in the air stream. Experience has shown that by proper design of the combustion chamber, proper arrangement of the ports, and adequate cooling fins, the side of the combustion chamber away from the direct air blast does not become overheated. (First article of a serial by C. Fayette Taylor in *Aviation*, vol. 18, no. 23, June 8, 1925, pp. 634–636)

Oil and Gas Power

Oil-Engined Locomotives—Fuel Oil and Its Supply—Trend of Oil-Engine Design—Oil Engines in Plants Requiring Steam—Gas-Fuel Problems—Oil and Gas Conservation—Salient Points of Papers Presented during Oil and Gas Power Week, April 20–25

DURING the week of April 20–25 more than 110 meetings were held in 34 states for the purpose of focusing nation-wide attention on the part of physicists, chemists, engineers, operating men, and the industries on recent progress and on immediate possibilities in the conservation of oil and gas for power uses. The participating organizations under whose auspices the meetings of Oil and Gas Power Week were held comprised national chemical, engineering and industrial societies, Government bureaus, local societies, local sections of national societies, schools and colleges, and other bodies interested.

The papers presented at the various meetings offer a survey of this most important industrial field. Unfortunately, however, only brief summaries of a limited number can be presented.

Oil-Engined Locomotives

Edwin B. Katte[1] read a paper on this subject before the Metropolitan Section of the A.S.M.E. on April 22. Mr. Katte pointed out that the oil engine had good prospects for use in switching because of its high tractive effort at starting and in acceleration up to three or four miles an hour. It had also prospects for use in residential districts for light-traffic main-line operation because of freedom from smoke and steam. The operation of the Diesel engine at constant speed and power enabled a smaller oil engine to be used at starting than would be the case with steam, but this characteristic at the same time limited the use of oil-engined locomotives to relatively light trains, if operated at high speeds. Two features requiring immediate development were: first, transmission apparatus, the electric drive being handicapped by its weight and high cost; secondly, a means of recooling the jacket water for the cylinders. Mr. Katte thought there was a distinct field for the oil engine in steam-railroad service in switching and in interchange of freight cars, and further that the first cost of oil-engined locomotive equipment, especially in yards, should be less than that of electrification, and that it would be as economical in operation as electric service. During the year several locomotives of this type, of between 800 and 2000 hp. would be put in experimental service on railroads.

At the same meeting of the Metropolitan Section, Elmer A. Sperry[2] discussed the Diesel-hydraulic locomotive. The thermal efficiency of the steam locomotive was of the order of 3 per cent, while that of the Diesel should have an overall value of 26 per cent, giving a saving in fuel of about 9 to 1. The great weight per horsepower of the Diesel had been its great drawback, and reduction of weight was a great problem. The second problem was the coördination of the peculiar power and torque conditions with the driving mechanism. To reduce weight, the mean effective pressure on the piston must be raised, more power must be obtained from the same volume of air employed, and the necessity for supercompressed air must be eliminated. Mr. Sperry pointed out that the compound engine afforded the highest results under all three heads. With the compound engine the mean effective pressure was 240 lb. per per sq. in. instead of 70 to 80 lb. per sq. in. and only 2.3 cu. ft. of air was required instead of 3.5 cu. ft., with perfectly colorless exhaust. Also the two-stage compression gave the compound the advantage of a large clearance volume, reducing the chilled walls to an insignificant ratio to unit volume, so that the widest possible range for solid injection, with all its advantages, was rendered available. In the application of the Diesel, the direct drive with the crankshaft as the jackshaft necessitated enormous air compressors to give reasonable starting characteristics, and this involved the serious disadvantage of enormous bulk and weight. The gear-clutch drive was impracticable above 250 hp. owing to clutch difficulties. The utilization of the exhaust gases to give moderate pressure to a boiler and an auxiliary starting steam engine involved great complication. Hence the hydraulic Lentz transmission had been developed, using a pair of rotary pumps, one the driver, the other the driven. This transmission had worked well, but with very low efficiencies. The subsequent introduction of a driving generator with variable piston stroke had been a step in the right direction, but ultimate success of the hydraulic drive would depend upon the application of a piston pump of the variable-displacement and pressure type to the driving part of the equipment likewise, eliminating the inefficient rotary motor. In comparing the electric and hydraulic drive as applied to the Diesel locomotive, Mr. Sperry pointed out that the hydraulic system was simpler and more mechanical; free from dangerous limitations of the time element of operation; was lighter than the electric system, and had the advantage over the steam engine that it worked exactly as the steam engine would if it were supplied with a variable-pressure boiler; the multi-cylinder hydraulic system was as smooth as electricity; the hydraulic drive was a constant-power drive, so that it was possible to obtain a super-tractive effort roughly up to one-third of the maximum speed of the locomotive; and finally, the hydraulic drive was not sensitive to moisture or water. Thus the hydraulic drive was seen to offer many advantages. Mr. Sperry further brought out the fact that the Diesel locomotive had separate units for its various functions, which gave great advantages from the repair point of view. Besides emphasizing the advantage of the hydraulic drive over the electric drive for the Diesel locomotive, Mr. Sperry made a strong argument in favor of the oil-engined locomotive as compared with electrification systems. He stated that the locomotive of the future would remain as it always had been, a prime mover. Better economy and greater capacity for work could be realized by a prime-mover locomotive than by main-line electrification with all its complex detail and enormous expense. Mr. Sperry also maintained very strongly that while the steam locomotive had developed wonderfully, the oil-engined locomotive would be its superior because of its greater thermal efficiency; a perfectly smooth starting torque held up to the limit of adhesion efficiency; greater acceleration and smoother handling of traffic; and because of larger power units within present roadbed limitations.

In discussing Mr. Sperry's paper, F. W. Mahl[1] said that Mr. Kruttschnitt, in a recent address, had mentioned that the Diesel engine showed the highest thermal efficiency of any known engine, in that 35 per cent of the heat energy of the fuel was transformed into work, or, four times as much as in the modern steam locomotive. And when the Southern Pacific had decided to order a Diesel locomotive this high thermal efficiency was an item of major importance. Other items that aided in reaching this conclusion were: (1) The Southern Pacific was singularly situated as regarded location of oil fields in California and Texas, which were in close proximity to the lines, thus reducing "long haul" of fuel; (2) eliminating fuel used in raising temperature of water in boiler to that of the necessary steam pressure; (3) eliminating fuel used in maintaining necessary steam pressure while locomotive was idle at terminals and on sidings; (4) eliminating fuel required in hauling a heavy tender; (5) this type of locomotive should be very desirable for use in arid districts where the conservation of water was an important factor.

Another Metropolitan Section paper was that of L. G. Coleman,[2] on internal-combustion locomotives. The rising cost of fuel, Mr. Coleman said, had emphasized the low actual thermal efficiency of the locomotive. Efforts to increase its efficiency had materially raised the first cost, both direct and indirect. The true cost of motive power was very obscure and no current figures showed

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[2] President, Sperry Gyroscope Co., Brooklyn, N. Y. Mem. A.S.M.E.

[1] Director of Purchases, Southern Pacific Company, New York, N. Y.

[2] Manager, Locomotive Department, Ingersoll-Rand Co., New York, N. Y. Mem. A.S.M.E.

it in its true light. Speaking broadly, the aim of most railroads was to effect operating economy by increasing train loads with heavier locomotives. For steam locomotives this involved in addition to increased strength of track the following expenses: longer stalls and pits; longer turntables; larger coaling plants; larger cinder pits; heavier machinery in shops and enginehouses; water stations of greater capacity; and larger standpipes and water mains. In the case of electric power none of these expenses were required, although many other overhead expenses were incurred. Mr. Coleman stressed as one of the principal advantages of the electric locomotive over the steam locomotive its greater readiness and availability for service. He thought that internal-combustion locomotives could be built with the same availability and serviceability as the electric locomotive, and owing to their thermal efficiency their power costs should be no greater. They would not require the extra cost and maintenance of the steam locomotive nor the auxiliary appliances required for electric locomotives. The field for internal-combustion locomotives would be limited only by the ability of the internal-combustion-engine builders to develop a machine of the reliability, economy and capacity of the electric locomotive.

FUEL OIL AND ITS SUPPLY

At the Richmond, Va., meeting on April 24, E. C. Wiley[1] read a paper on Fuel Oil, Its Supply and Efficient Use. Fuel oil, the residue left over from the country's supply of crude petroleum, said Mr. Wiley, met special requirements so well as to be too valuable for squandering in more ordinary uses, even when prices permitted this. The engineering profession was therefore vitally concerned with its conservation. Mr. Wiley quoted some interesting statistics. According to an editorial in *Power*, he said, the total oil production of the world in the 66 years preceding 1924 had been 11⅓ billion barrels, of which the United Statdes furnished about 63 per cent. The estimated reserves of the world according to Dr. J. B. Sears were approximately 42 billion barrels, of which this country was estimated to have 7 billion. In bituminous, anthracite, and lignite coal we had 3527 billion tons left. On a heat-unit basis the ration of available coal to oil in this country was about 1680 to 1. The editorial had expressed the opinion that the flush production of the last few years had stimulated the use of oil in plants where it would not be justified under ordinary conditions, and that this, together with the pitiful waste under present competitive conditions, would soon deplete our entire supply. Coöperation among producers, pooling of interests, elimination of excessive drilling of wells, were some of the remedies now being suggested. Discussing the possibility of obtaining oils from bituminous shales, Mr. Wiley thought this opened up a field of far-reaching importance and offered the possibility of a supply that would exceed by far that contained in the liquid pools of the world. There was possibly sufficient oil-bearing shale to supply the liquid-fuel demands of the world for many generations, but this would only be obtainable at increased cost, which but emphasized the doctrine of conservation. There was also a possibility of obtaining an unlimited oil supply from high-volatile coals, but there were no reliable data as to the cost of the process involved. In fact, it was probable that the use of solid fuel would be relegated to second place in favor of the more convenient liquid and gaseous fuels. Other sources of oil supply might readily supplant the liquid-oil sources now being so rapidly exhausted, nevertheless the moral remained that a period of economic and technical proficiency in bringing the remaining supply of our crude petroleum into effective service was now approaching. Discussing the supply of fuel oil in the United States and its increasing use and output, Mr. Wiley pointed out how much the West was dependent on fuel oil in view of the absence of an adequate supply of coal. Oil prices in spite of many downward reactions were trending sharply upward. Mr. Wiley then passed on to a discussion of the present uses of fuel oil. In shipping, at the beginning of 1921 the world's tonnage amounted to 55 millions. Of this tonnage about 9 millions was already on an oil-burning basis, with 1 million fitted with Diesel engines. The shift from coal to oil was being accomplished partly by the very wasteful conversion of coal burners to oil burners, and partly by the much more desirable use of Diesel engines. In the locomotive field there was similarly a very urgent need for the use of Diesel engines in lieu of the wasteful practice of burning oil under steam boilers, where of an annual consumption of 60,000,000 bbl. of petroleum only two or three per cent of the heat value was delivered at the drawbar. Mr. Wiley, in common with other authors of papers presented during Oil and Gas Power Week, spoke with approval of the efforts being made in various quarters to use Diesel-electric locomotives, mentioning construction by the General Electric Co. and the Baldwin Locomotive Works. Discussing the question as to whether fuel oil should be used in general power plants, he pointed out that the answer depended purely on economic considerations. The best efficiencies with oil-fired boilers hardly exceeded 82 per cent under the most favorable conditions. With coal, efficiencies of 80 per cent had been realized. On the basis of these figures, the actual fuel cost in modern steam plants would run approximately 41 per cent less for coal than for oil. It was only in rare cases that oil would be more economical, and it was in general an abuse of the principles of conservation to use fuel oil in power stations. The use of fuel oil in connection with the automobile, Mr. Wiley thought, entailed an appalling waste of our resources.

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THE MOTOR-FUEL SITUATION

In a general paper presented during the Week, A. J. Kraemer[1] discussed the motor-fuel situation. The great increase in the last few years in the numbers of users of petroleum products had awakened considerable interest in this product. In some very interesting statistics, Mr. Kraemer showed that the number of cars and trucks in service had increased about 185 per cent from 1918 to 1924, and the domestic demand for gasoline from 3,129,266,000 to 7,780,625,000 gal. in the same period, or a gain of 149 per cent. During the same period the production of crude oil in the United States had increased 100 per cent. The number of automobiles and trucks in use had increased in about the same ratio as the domestic demand for gasoline, and it was also interesting to note that the consumption per motor per year had become relatively stabilized at something like 445 gal. The number of automobiles in the United States at the end of 1924 was 17,592,000, an increase of 2,500,000 for the year. It seemed entirely likely that the demand for gasoline would increase with further increase of automobile registration. On the other hand, it was possible that the increase in production of crude oil would be small. There were other disturbing factors in the situation such as the dropping of production in Mexico, while at the same time other industries had shown increasing interest in fuel oil. Increasing demand for fuel oil might make it actually unprofitable to "crack" fuel oil into gasoline, unless the price of gasoline was also increased. Summing up a very valuable discussion, Mr. Kraemer indicated that (1) domestic demand for gasoline was increasing steadily; (2) demand was becoming stabilized in terms of consumption per motor per year; (3) definite progress had been made toward more efficient utilization of petroleum and its products; (4) anti-knock mixtures might increase the efficiency of fuel; (5) various substitutes were available at higher prices than were being obtained at present for gasoline. The more distant future appeared problematical, but it seemed that there would be for some time a sufficient supply motor fuel although it was probable that it would be more expensive in proportion to the general run of prices than it was today.

TREND OF OIL-ENGINE DESIGN

On April 17, Forrest E. Jones[2] read a paper at the University of Kansas on the trend of oil-engine design, and gave a brief historical review of the subject in general. The Hornsby-Akroyd engine was the forerunner of the low-compression engine, which had a compression pressure of from 80 to 150 lb. per sq. in. For use with heavy oils, vaporizers, hot bulbs and hot spots were utilized to secure combustion, with fuel injection so timed that burning started just before the upper dead center, with slight variation in the injection point for various grades of fuel. In the semi-Diesel engine a total pressure of from 500 to 600 lb. per sq. in. was reached, and burning at constant pressure was often closely approximated. Pump and air injection were used, together with some exterior

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heating element as in the low-compression type. On the whole, there was some advantage in the semi-Diesel over the low-compression type. With a better combustion-chamber design and higher compression pressure a cold-starting or full-Diesel engine type had been arrived at which had the advantages of eliminating the starting torch or other apparatus, lower fuel consumption, greater reliability, and the possibility of using heavier grades of oil. These three types might be compared on the basis of the following table:

Type	Compression, lb. per sq. in.	Maximum pressure, lb. per sq. in.	Fuel	Fuel, lb. per hp-hr.	Sizes, hp.	M.e.p., lb. per sq. in.	Weight, lb. per hp.
Low compression	80 to 250	400	Kerosene distillate	0.7 to 1.0	5 to 125	40 to 60	75 to 125
Semi-Diesel	200 to 300	600	Distillate fuel oil	0.5 to 0.75	50 to 180	50 to 70	150 to 250
Diesel	300 to 500	600	Any grade good oil	0.4 to 0.45	10 to 1000	70 to 100	200 to 450

In addition to the advance in type, there had been progress in detail design and in reduction of weight and bulk. The Diesel engine itself could be classified according to the method of injection of the fuel: gaseous, air, and pump injection. In the typical gaseous method such as the Hvid, air entered a small chamber on the compression stroke, supported combustion of a small amount of the fuel, and the rise in pressure expelled the remaining fuel into the main chamber in the form of a spray. In the well-known air-injection system, air compressed to some 900 lb. per sq. in. drove the oil through a series of grooves and perforated plates into the compressed air of the combustion chamber. In the pump-injection engine the cycle was identical with that of the air-injection engine, only that the fuel was injected by a pump and not with air. The air compressor was eliminated and the mechanical efficiency was increased. The Diesel engine of the present day, said Mr. Jones, was simple and reliable, and fuel-injecting and atomizing apparatus had been highly developed. The value of n was from 1.15 to 1.30 and the efficiency around 33 to 35 per cent, or about 75 per cent of that possible. Its reliability was indicated by the statement of one manufacturer that the maintenance cost of 65 of their engines one year old or older was 2.1 per cent of the purchase price per year.

At the Engineers' Club of Baltimore, on April 22, Leon Wygodsky[1] read a paper on oil and gas engines which was of a historic and general character and contained much material not covered by other authors during Oil and Gas Power Week. Only the salient points of this paper can be presented here. Why, asked Mr. Wygodsky, was the oil engine so slow in taking root in the United States? Dr. Diesel, while lecturing before the A.S.M.E., fourteen years ago, had given the true reason: with cheap labor and fuel, the wasteful steam engine was considered economical enough. It was the European war, and more specificially the spectacular work of the German submarines—all equipped with Diesel engines—that had served to advertise this engine in the United States to such an extent that now every oil engine in this country was called by that name, with injustice to many workers in the field. In classifying the oil engine along conventional lines, the author allotted a place to his own self-starting engine. In this type of engine great simplifications have been obtained, as storing of compressed air for running and starting of the engine had been made unnecessary. The outstanding features of this engine were: (1) air compression to about 300 lb. per sq. in., the temperature of which was sufficient to ignite the fuel charge when the engine was under running temperature; (2) a temporary ignition device consisting of a hollow circular tube, surrounding the spray nozzle, which although totally enclosed within the water-jacketed cylinder head, could still be made red hot by outside means without resorting to electrical devices; (3) a special torch using the same fuel oil as the engine; (4) an airless atomizer which broke up the fuel very effectively and with great precision; (5) a locking device for the flywheel whereby the flywheel was retained in a certain position and released only after sufficient pressure was developed behind the piston. At the present moment the marine oil engine weighed somewhat more than a corresponding reciprocating steam engine or turbine, but advantages in fuel and labor made it a profitable investment. Mr. Wygodsky stated that reduction in weight and cost of the oil engine would make its universal application irresistible. To appreciate the situation, he made the following comparison: In a locomotive engine having a boiler pressure of 200 lb. per sq. in. and operating two double-acting steam cylinders, the m.e.p. was almost 200 lb. per sq. in. In a four-stroke Diesel engine with a m.e.p. of about 100 lb. per cycle, the pressure was only 25 lb. per stroke. This meant that it would require 16 Diesel cylinders of the same diameter to obtain the maximum effect that was possible with one double-acting steam cylinder, or 32 cylinders to complete the same locomotive. An oil engine or an oil locomotive could not, therefore, be built on conventional lines. To reduce the number of cylinders and weight the following was being done: first, the adoption of a two-stroke-cycle system to halve the number of cumbersome working cylinders (Mr. Wygodsky was hopeful of progress in this direction); secondly, double-acting cylinders, mostly built on the two-stroke cycle, which only recently had managed to overcome the difficulties of heat stresses, stuffing boxes, etc. Under the last group were included all engines in which two pistons operated in the same cylinder structure. Mr. Wygodsky gave descriptions of the Junkers, the Cammelaird-Fullagar, and his own engine as promising examples of this type. Thirdly, the supercharging of engines by which the amount of air trapped in a cylinder was increased, so to speak, artificially, and a larger amount of oil was burned with correspondingly greater m.e.p. Fourthly, the adoption of high-speed engines with small diameters and stroke. This was permissible in internal-combustion engines, particularly in view of the fact that a small internal-combustion cylinder gave practically the same fuel economy as a very large one, the opposite being the case with the steam engine. The reason for this reduction in weight was the fact that whereas the output of a cylinder grew as the square of the diameter, the weight of the engine increased approximately as the cube of the diameter. In the high-speed internal-combustion engine, however, speed reduction became important. Although the high-speed engine might wear out more quickly, its initial economy might yet make it more economical. Fifthly, airless fuel injection. Compressed air being so expensive to obtain and introducing so many complications, Mr. Wygodsky saw great possibilities in the introduction of the airless or solid-injection type. Sixthly, the utilization of the waste heat of the oil engine in exhaust boilers for power and heating purposes, making the oil engine a still more economical machine.

[1] Chief Engineer, Baltimore Oil Engine Co., Baltimore, Md. Mem. A.S.M.E.

Oil Engines in Plants Requiring Steam

L. H. Morrison[1] contributed a very thorough general paper on the use of oil engines in plants requiring steam. In states west of the Mississippi and east of the Rocky Mountains the internal-combustion engine prevailed partly because coal was hard to get and partly because no heating was required. In the eastern states, or at least in those north of Mason and Dixon's line, steam heat was required during from five to seven months of the year and steam was often required for processing. In respect to the industrial plant, there was seemingly a tradition that the need of steam or hot water at once precluded the oil engine from consideration. The author examined this tradition carefully from a number of points of view, taking into consideration the character of the steam required, the comparative costs of steam- and oil-engine power, the amount of heating required under varying atmospheric conditions and other factors. His general conclusion based on this exhaustive analysis was that the superior efficiency of the Diesel engine made its use worth while, even in plants where large quantities of steam were required. The amount of steam required for heating or processing could be efficiently obtained from the steam plant; the oil engine would take care of the rest of the requirements, and its superior efficiency would more than justify the added investment. There was also the added possibility of using the heat usually wasted in the oil engine's cooling water and exhaust. At any rate, the combined oil and steam plant was well worth considering in many and varied industrial plants.

Gas-Fuel Problems

Industrial gas formed the subject of a paper read by C. B. Phillips[2] at the meeting of the Virginia Section on April 24. The keynote of

[1] Associate Editor, *Power*, New York, N. Y. Mem. A.S.M.E.

[2] Richmond, Va.

the paper was the conservation of natural resources by the full and skilful utilization of gas fuel. The growth of the gas industry was enormous, the total sent out in cubic feet in 1910 being 150 billion, and in 1924, 320 billion. Gas was a major by-product of coal and provided one of the most powerful methods of conservation. We consumed 600,000,000 tons of coal annually, and Mr. Phillips estimated that three-quarters of this was wasted. In burning coal in coke ovens, for example, the high flames shooting up from the stand-pipe represented waste, and there was also waste of valuable by-products such as tar, benzol, etc. Fuel oil would soon be exhausted, particularly in view of the wasteful competitive and merchandising systems employed. As the by-products of oil were better utilized its price might also go up so much that it might be eliminated from the industrial field. When considering electricity, Mr. Phillips agreed that it was equal to gas in many applications from the point of view of transportation and control, but was not so economical. From the standpoint of generation cost, gas was approximately five times cheaper than electricity. The economics of the case being in favor of gas, the thing was to establish a working policy which would enable gas companies to obtain a greater distribution of industrial gas on a competitive fuel basis. This policy would entail lower heating standards to be accepted by state public-utility commissions. The central-station gas company must also change from a domestic-service organization primarily to a plant giving complete and economical service to industrial plants. Having produced gas on the most economical basis and under broad and fair regulation, equitable rates must be worked out under the basis of the "three-part rate," with costs divided into three main divisions: a customer's cost, to cover general overhead expenses; a demand cost, which would represent that item of cost occasioned by the gas company's being ready at all times to supply the maximum demand of the customer; and a commodity cost, which would represent a manufacturing and distribution charge and be proportional to the amount of gas that the customer used. Also it must be realized that an appreciable amount of industrial gas at approximately 80 per cent of the domestic rates could not be sold in great quantities. Industrial gas had also oftentimes lost a good customer to electricity due to the fact that efficient equipment was not procurable for gaseous fuel, there being no appliance manufacturer in the gas industry comparable to the General Electric or Westinghouse in the electrical industry. In furnace work the reason electricity had stepped into the industrial field was due to the fact that the electrical man never tried to convert old and inefficient equipment, but would only sell the very highest type of equipment with all accessory control equipment. Quite a good deal of gas-equipment development was now taking place with recuperation, combination recuperation, and surface combustion single-valve-control burner equipment among other items. Mr. Phillips discussed at some length methods of combustion and predicted further that future developments would not be dramatic but would follow a steady evolution. Combustion with proper mixture of air and gas was one of the objects to attain. A useful method of working was that of the continuous furnace, in which the work was fed continuously from one end. Recuperation linked with firing equipment which automatically controlled the equipment had been one of the successes of the past year.

Economy of Gas Blowing Engines

C. G. Sprado,[1] on April 8, read a general paper on the economy of gas blowing engines. About twenty-five years ago the Cockerill Company of Belgium had called attention to the possibility of building gas engines in large units and to the fact that blast-furnace gas was the ideal fuel for such engines. While European practice had given much attention to the furnace-gas engine, American steel makers had shown but little interest in the gas engine, because of cheap coal, fuel cost being relatively unimportant and tonnage being considered of more importance than reduction in cost of the product. The first American blast-furnace-gas engine was operated at the plant of the Lackawanna Steel Company in Buffalo only in 1903–1905, but up to the present time there had been installed in America in steel plants 118 gas blowing engines having a normal capacity of 3,591,000 cu. ft. per min., and 110 gas-electric units having a capacity of 275,000 kw. While primarily a smelter, the blast furnace was important as a gas producer as one-third of the total heat in the coke remained in the gas after taking care of furnace requirements as to stoves, waste, and miscellaneous uses. The amount of gas produced per ton of pig varied with the coke ratio per ton of pig, which varied from 1800 to 2700 lb., while the heat value of the gas ranged from 90 B.t.u. per cu. ft. to 105 B.t.u. for the higher coke ratios. After stove heating the first opportunity for conserving gas was in the employment of blowing machinery of the most economical type. Gas blowing engines were generally of the four-cycle double-acting type, with the air cylinders directly in line with the gas cylinders, with the engines of the tandem type having two double-acting gas cylinders for each double-acting air cylinder and arranged either as twin or single machines. For the efficient operation of a furnace it was necessary to deliver a predetermined quantity of air at a uniform rate, and modern gas blowers kept the speed automatically within 0.5 r.p.m. The design of air cylinders or "tubs" had greatly changed from the positively operated inlet and outlet valves to plate valves for both the inlet and discharge. These valves could be placed in the cylinder heads or in belts surrounding each end of the cylinder, the latter design having such advantages as large valve areas and cylinder heads removable without disturbing the air connections. Fifteen years' experience had shown that blowing engines were fully the equal of steam in reliability. By careful calculations and analysis the author showed that the operating and maintenance charges were as low as those of any other type of apparatus used for this purpose, and the records also showed that they maintained their thermal efficiency unimpaired after fifteen years or more of constant service. As an example of the enormous savings possible, the following figures were instructive. In 1920, in the Pittsburgh district the total power fuel was the equivalent of 7,830,000 tons of coal valued at $32,000,000. If the gas had been used in gas engines there would have been a saving of approximately $8,000,000.

Conservation in the Field

At the Los Angeles Section, on April 23, R. R. Templeton[1] presented a paper on oil and gas conservation in the field, covering every important method of conservation employed. Petroleum because of its inherent qualities and the wide range of boiling points of its hydrocarbon fractions, he said, was a difficult thing to conserve and oil field "losses" or "wastes" occurred in many ways. With present-day methods of drilling and producing oil wells, about 75 to 80 per cent of the oil originally contained in oil sands was left underground after the wells had reached their economic limit of working. Increased yield was new being obtained by many devices. Gas was the motive force moving oil through the sands to the wells and it was necessary to hold back pressure on oil sands and prevent gas from bypassing the oil. In California wells were tubed, with oil and gas flowing through small-diameter tubing; "beans" or chokers were inserted in flow lines; pumping wells were tubed so that they would not pump down to a point below the top of the oil sand. Improved technique in drilling and solving geological and engineering problems was important. Watching of production records and changes in equipment was helpful—notably changes in pumping equipment by lifting devices that operated automatically by compressed air or gas, thus doing away with sucker rods. Cleaning must be carefully done. A new process employed air or gas under high pressure to blow obstructions out of the hole. Heat and solvents were used to dissolve waxy deposits and reduce viscosity. Controlled water drives had shown superiority over pumping methods. Gas or air introduced to restore pressure artificially had largely increased ultimate production. Vacuum pumping temporarily improved production but had no very pronounced advantage. Extraction of oil from fine-grained, compactly cemented sands has been materially assisted by "shooting" with high explosives. Mining methods resulted in extracting the greatest possible amount of oil, but were expensive and dangerous. The spacing of wells to obtain the greatest amount of oil with the least number of wells was receiving careful consideration. Premature flooding produced serious losses by isolating and trapping large quantities of oil, and this problem was receiving attention. Emulsions formed by the agitation of water and oil in the presence

[1] Engineer, Allis-Chalmers Manufacturing Co., Milwaukee, Wis. Mem. A.S.M.E.

[1] Union Oil Building, Los Angeles, Cal.

of some inorganic substance were now being treated by (1) electrical dehydration, (2) chemical dehydration, (3) centrifugal dehydration, (4) dehydration by filtering, (5) dehydration by heat and pressure, and (6) dehydration by washing with hot water. To minimize the formation of emulsions, checking of the flow velocities was sometimes resorted to. Wasting of gas reached its highest expression in high-pressure town-lot fields where a multitude of different operators and land owners were all striving to obtain their share of production before the others got it. In new fields there might be incomplete recovery of oil; incomplete recovery of gasoline because of lack of facilities; and wasting of excess gas. Evaporation might account for the loss of 6 per cent of gasoline before the oil reached the refinery. Methods to combat this were storing in vapor-tight tanks; in tanks under roofs that floated on the surface of the oil and effectively sealed the air from it; storing in tanks in which temperatures and pressures were reduced by water tops, water sprays, etc.; and installation of conservation plants by means of which gasoline was extracted from waste vapors. Surface wastes in the form of leakage, drainage, and soakage had been reduced to a minimum in the California oil fields. The tremendous wastes by fire were being reduced by the use of steel vapor-tight tanks, water-sprinkler systems, and by general care in many ways. The increasing demand for natural gas as fuel for domestic purposes had led to conservation. The subject of field boilers was receiving much thought on the part of oil companies, with careful investigation of problems of radiation and maximum efficiency in accordance with modern ideas. This brief statement, said Mr. Templeton, summarized the most important methods employed hitherto.

Conservation in the Refinery

Another paper dealing with the topic of practical conservation was one by R. G. Lovell,[1] on conservation in the refinery, read at Los Angeles on April 23. Mr. Lovell pointed out that the refining of petroleum on the scale upon which it was now carried on was rather young and therefore opportunities for conservation were greater in number and more tangible in evidence than in factories carrying on manufacturing processes. Waste in the refinery might be classified as follows: that due to loss of gases through evaporation in storage; that due to failure of equipment; losses of lighter oils due to improper separation; and secondary losses through the use of inefficient apparatus and lack of proper protection against fire. In handling evaporation in storage due regard must be paid to well-known laws of physics, and some steps must be taken to retard as much as possible the absorption by the shell of a steel tank of the heat of the sun's rays. The simplest method of retarding the heat absorption was by the application of a paint light in color, and the selection of a pigment to give the best results was important. It had indeed been shown that aluminum when combined with the proper vehicle had a greater refractive power than even the best white paints; and that a properly prepared and applied aluminum paint had greater covering capacity than any other practical paint mixture, and further, had a life and resistance to sulphur fumes at least equal to that of any of the usual zinc paints. The opacity of the mixture was such that a single coat would cover a dark-brown or even black undercoating perfectly. The pigment was composed of the highest grade of polished varnish powder and a vehicle of the best quality suited to the peculiar requirements of a pigment like aluminum. The cost of such a pigment was less than that of any other good paint. It should be noted that added losses by evaporation were not caused so much by absorption by the contents of the tank of the sun's heat as by absorption of the heat by the steel shell and roof which was then transmitted to the gas over the surface of the oil, thereby increasing the vapor tension and pressure of the gas. While the painting of the tank with an aluminum finish gave very good results, a more important step was in the application of a jacket composed of an asbestos-wood material in corrugated sheet form, suitably supported by angles and clips. A framework separated the jacket from the surface of the tank by some five inches and, as the bottom and top were left open, an induced circulation of air was caused which so reduced the heat bearing upon the shell of the tank that a very substantial reduction in evaporative losses was had. As well as holding the formation of gases to a minimum, thought should be given to handling such gases as must inevitably form. Temperature within the tank caused the gas pressure to rise, and if this pressure was permitted to escape a means must also be provided for the condition of partial vacuum when the temperature again fell. A very practical device for this duty was a pressure and vacuum relief valve using the hydraulic sealing principle. The common practice of free exits to the atmosphere either directly over the tank or through lines terminating in a trap, constituted a severe fire hazard and had nothing to recommend it except cheapness. Particularly dangerous were such methods in the presence of lightning. The fact that the gases arising from the oil in tanks frequently had a volatile liquid content of from $^1/_2$ to 1 gal. per 1000 cu. ft. made its recovery a thing worthy of considerable treatment. This recovery was accomplished by means of a piping system liberal in size and equipped with exhausters of the rotary type. The rich gas was passed through an absorption plant, and after the liquid content had been removed the dry gas had a heating value approximating that of natural gas. It might be thought that the greater part of the losses likely to occur in a large refinery would come from the large amounts of products usually in storage. This was not the case because the tanks were in plain sight and the leaks were immediately visible. Not sufficient attention was given, however, to reliable fittings, and Mr. Lovell strongly recommended the discarding of such fittings as cheap standard cast-iron valves. To avoid losses in suction and charging lines, rigidity of connection must be avoided by the use of four-ell swings and pipe bends, and where there was sufficient bearing power of the soil, a steel-reinforced concrete ring of liberal dimensions was provided. To protect against loss of the contents by boiling over in case of a fire either concrete or earthen dikes were provided which were sufficient in length and height to contain from 100 to 150 per cent of the rated capacity of the tank so protected. An oilproof elastic compound was applied to interior seams and rivet heads and served to prohibit the minor tank leaks which, while not likely to cause serious losses, gave a bad appearence to the exterior. To protect against loss of products from failure of pipe lines within the refinery, a system of concrete pipe trenches connected at frequent intervals to the sewer system should be provided. A secondary opportunity for conservation which Mr. Lovell nevertheless thought of the utmost importance was in the improvement of the pumping apparatus, with the steam turbine or electric motor displacing the reciprocating engine. Mr. Lovell also touched briefly on the subject of loss of lighter oils due to improper separations, and stated that in his opinion the design of the installation units might be carried out in such a way that complete and proper separation of all the various fractions desired could be obtained with minimum operating expense.

[1] Assistant Chief Engineer, Pan-American Petroleum Refinery, Wilmington, Del.

The Future of the Steam Engine

THOSE engineers who, for more or less sentimental reasons, have deplored the supersession of the steam engine by the internal-combustion engine, may take heart at the forecast of Dr. John S. Haldane, president of the Institution of Mining Engineers. At the annual meeting of the Institute, which was held in Cardiff on June 16, both Mr. Haldane and Sir John Cadman suggested that the present extensive use of oil fuel was only a passing stage, and that coal would reconquer many of the fields of utility which have been invaded by oil. As regards the relative merits of steam and oil engines, Dr. Haldane said that he believed steam engines would, in the not very remote future, take the place of internal-combustion engines in many cases where internal-combustion engines are now employed. In a steam engine, he said, jackets were used to conserve heat in the cylinders, but in an oil engine it was necessary to waste heat to keep the metal of the cylinders at a safe working temperature. The future development of the steam engine would be along the lines of higher pressures, with smaller boilers and lighter engines, so that in all probability they would be more suitable than petrol engines for aeroplanes and motor cars. He did not think that steam engines and internal-combustion engines would ever fight, but believed that the steam engine would beat its competitor. (*The Engineer*, June 19, 1925, p. 669.)

Steel-Foundry Management

By R. A. BULL,[1] CHICAGO, ILLINOIS

The author discusses those steel-foundry problems that in his opinion have the greatest general significance in this highly specialized branch of manufacture. He presents a brief analysis of the industry, explaining its technical and commercial divisions, and the significance of each from the standpoint of output, for the purpose of more clearly indicating the nature of the industry under consideration.

The branches of a company organization are assigned to staff and line departments. Reasons are given for certain classifications, regarding which procedures occasionally vary. Policies governing staff departments are discussed separately, not for the purpose of enumerating all duties ordinarily performed, but with the intention of provoking discussion regarding certain factors considered by the author to be of fundamental importance, about which there are differences of opinion.

The subject of compensation both for workmen and for foremen is emphasized because the author believes this is a detail of management which is of very great significance.

THERE are several general divisions into which the steel-casting industry technically separates itself. The first of these is the open-hearth, which is much the largest. Statistics credit the year 1917 with the greatest output of open-hearth steel castings produced in the United States, viz., 1,357,700 net tons. Of this output 54 per cent was basic and 46 per cent was acid.

The second division from the standpoint of volume of output is that of the electric furnace. The output of electric-steel castings has reached an annual total of 255,000 tons, approximately 16 per cent of all the steel castings produced yearly in this country. Nearly all of the electric-steel castings made in America are of acid metal, presenting in this respect a decided contrast with relation to the fairly equalized selection of acid and basic linings for open-hearth furnaces in the foundry.

The third technical division is that of the converter. At present the tonnage of converter castings is about one-fourth that of electric-steel castings.

The fourth technical division is that of the crucible. It is doubtful if today any crucible-steel castings are made in America, except in a few instances for home consumption of the product, and this division can therefore be disregarded.

Considered from the standpoint of industrial grouping, steel-casting manufacture divides itself in a different way from that just indicated. Three rather distinct classifications exist, as follows:

(*a*) Open-hearth foundries (generally acid) producing steel castings of sections varying from medium to very heavy, with overall dimensions covering a wide range.

(*b*) Open-hearth foundries (generally basic) delivering a product principally consisting of repetition work in the nature of specialties for railroad use. Such castings are almost invariably of moderate sections, and only a few foundries making this product produce specialties having large overall dimensions. Most of the castings in this class are of average proportions.

(*c*) Electric foundries (almost invariably acid) and converter foundries (always acid), generally specializing in castings of thin sections and small or medium overall dimensions.

Comparing the average-size open-hearth foundry with either the electric-steel or converter foundry as commonly found, there are great differences aside from melting units and other equipment. The distinctions are magnified in the cases of the largest open-hearth foundries and the smallest electric-steel or converter foundries. Many of the characteristics distinguishing each of the two general types are unrelated to the large differences in average tonnages produced in them.

It thus will be appreciated that managerial methods should be considered with relation to the type of steel foundry under consideration. In this as in other industries there are fundamental principles that can be effectively applied, irrespective of size of output or kind of foundry. Further, there are many details of significance only in the division into which the plant naturally falls.

Variety of Vocations

There is no other branch of industry in which the regular operations create as heavy a demand as is made by the steel foundry upon the combined knowledge of the mechanical engineer, the metallurgical engineer, the chemist, the physicist, and the experienced manager of men. One important division of steel-casting work leans heavily on the creations of the expert electrical engineer to supplement the list of technical and scientific requirements.

Many engineers have an inadequate appreciation of the complexities of the steel-casting industry, presenting management problems caused to large extent by the many skilled operations required. A factor of great significance in the manufacture of steel castings is the relative importance of the "personal equation." Labor costs represent approximately half of the total costs of making steel castings.

Some persons, including industrialists, distinguish between skilled and semi-skilled occupations by making the following classifications: Trades that are most commonly known to the average man, each of which has relatively large numbers of craftsmen; and occupations the extent of each of which does not require many workmen or the nature of which is not familiar to the average citizen, who is apt to consider a skilled trade as one that is wholly or partly unionized. The author wishes to make the point that many skilled trades are erroneously regarded as semi-skilled, due to unfamiliarity of many persons with the work involved. It requires much more skill to be a thoroughly competent operator of a pneumatic chipping hammer in a steel foundry than many engineers realize, and probably more skill than is displayed by the average carpenter or bricklayer.[1]

Classification of Staff Departments

It can be appreciated that the work of running a steel-casting plant should be organized and directed with special care. This leads us to a consideration of the division of responsibilities and the coördination of departments in a steel foundry, operated by men who have headquarters where the product is made.

The first group to be considered is what might be termed the staff organization, the members of which report direct to the principal company executives or to related staff departments. The sections regarded by the author as coming under this general heading are as follows:

1 Sales	5 Drafting	9 Inspection
2 Accounting	6 Order or Schedule	10 Construction
3 Purchasing	7 Research	11 Service
4 Cost	8 Metallurgical	

The inspection of the product is a detail that is sometimes given to the superintendent to direct. If the chief inspector reports to the shop superintendent, the author believes a hazard is unwisely assumed that may react to the disadvantage of the consumer, and ultimately to the producer. The up-to-date steel foundry is operated on the principle that the interests of the buyer and the seller are mutual. It is sometimes extremely difficult to decide whether a steel casting should be scrapped or shipped after further treatment. It is impossible to prepare general or specific instructions to cover many points daily requiring decision in the conscientious inspection of steel castings. The proposition largely resolves itself into the exercise of good judgment. For this there often is required a practical knowledge of the use to which the casting would be put.

In the necessity for making very fine distinctions between what

[1] Director, Electric Steel Founders' Research Group.

Contributed by the Management Division and presented at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of The American Society of Mechanical Engineers. Abridged.

[1] The unabridged paper lists 26 skilled operations found in the average steel foundry; and fifteen additional occupations requiring experience typical of some steel foundry operations.

is good enough to use and what is bad enough to discard, an employee working under the direct authority of the shop superintendent must reflect the latter's judgment in general. He must do what his superior definitely instructs him to do with respect to a particular casting. The superintendent is frequently under pressure to get the largest possible output at the lowest possible cost. Sometimes there is coupled with these requirements a demand for very high quality. The three things cannot always be done at the same time. The desire to do them and thus gratify the management is apt, consciously or unconsciously, to influence the man under fire. The result may be inadequate consideration for the customer's requirements, and for the reputation of the foundry.

The only practical means of safeguarding against the exercise of poor judgment in the examination of castings for shipment is, in the author's opinion, to place the chief inspector completely under the jurisdiction of a company executive, who is not as readily influenced to form judgment from a restricted viewpoint as is the average superintendent.

It is frequently advisable to place the chief inspector under the sales manager, when the president or plant manager prefers not to direct this detail. If the sales manager, is, as he should be, properly qualified by practical knowledge of shop operations, the author believes he is ideally fitted to supervise the inspection department. It is he who will be most handicapped in the future if the consumer receives unsatisfactory material.

The metallurgical department is listed under one of the chief company executives, for the reason that the importance of questions and practices related to the metallurgy of steel are such as to require all the judgment that can be exercised. If the plant manager, to whom appropriately the metallurgical department can report, feels incapable of personally settling a question, he always has recourse to the opinions of his practical shop men. Having these to supplement the sound judgment supposedly characterizing a manager, questions relating to the chemical composition and the physical properties of the metal, and to the details of melting and heat-treatment practice, are most apt to be decided wisely. It is appropriate to state here that metallurgical problems are much more numerous and frequently more difficult of solution in the steel foundry than they are in the steel mill, when comparable conditions as to variety of metals obtain.

It is sometimes found most satisfactory to put the order or schedule department jointly under the direction of the sales manager and the plant manager. The sales department, which sometimes exclusively controls the preparation of foundry schedules, may be influenced too much by the pressure of insistent customers, even though they may have no justification for complaint from the standpoint of commitments. A subordinate in the sales organization who receives repeated and exasperating demands for better service than has been promised or can reasonably be expected, is apt to transmit the pressure to individuals in the shop, who may have to be guided by resulting instructions, regardless of their effect on general operations.

It is generally most effective to have under the manager a works engineer to supervise construction and maintenance, to whom the master mechanic may suitably report. This engineer should constantly give attention to power conservation. This includes looking for air leaks, providing, with the least amount of current, the proper amount of artificial light suitably located, the reasonably frequent cleaning of windows and skylights to reduce the required amount of artificial illumination, the systematic upkeep of buildings, and the intelligent direction of all repair work on equipment. For this purpose the works engineer should have access to correct records showing the allocation of maintenance expense charged to individual items, all of which should be plainly identified in the shop.

Classification of Line or Shop Departments

In designating the departments to be headed by the shop superintendent, certain selections ought to be governed by the personal qualifications of the superintendent. In most cases it has been sufficient and satisfactory to give this official jurisdiction over the following departments: patternmaking, molding, core-making, flask repairing, melting, pouring, shaking out, cleaning, heat-treating, and shipping. The innumerable details included in the execution of these duties keep a very industrious and systematic man busily engaged. If the foundry is not of the smallest size, the superintendent should have several assistants. One such should have jurisdiction over both molding and coremaking in any case, and in some cases, patternmaking as well. Another assistant can appropriately be delegated to follow intensively all work in cleaning, heat-treating, and shipping. It may be practical to give this latter assistant certain other duties in keeping with his former experience and particular ability.

There should be a head molding foreman, the number of whose assistants is governed by the number of molders. The core room must have its foreman, and in many cases he needs a subordinate of the type ordinarily termed "straw boss." Cleaning operations include flogging, torch cutting, sprue cutting, chipping, grinding, blasting, tumbling, and welding. Such work includes so many details of importance that one or more foremen may be required to supplement the activities of the delegated aide to the superintendent.

Some steel foundries produce sufficient tonnage to require considerable unskilled labor in many departments. For this purpose a "floating gang" is sometimes most suitable. Such a group should be under the control of a general labor boss reporting to the shop superintendent and, in addition, taking instructions from his assistants and sub-department heads. In a fairly large steel foundry there are innumberable things to be done requiring the cheapest class of labor, and a properly constituted labor gang can invariably be kept busy, conserving the time of better-paid workmen.

In shops where night work is necessary, it is generally best to have those in charge of the crews on the night shift report to one man in general charge, who receives his instructions both from the shop superintendent and from the day sub-department heads.

In pointing out that melting should come under the shop superintendent and that the heat-treatment ovens should come under one of his assistants, reservation is made regarding orders to govern manipulation, transmitted by those higher in the organization, for the execution of which the shop men mentioned should be responsible.

The general scheme outlined has worked well in certain foundries of average size and character. There is, however, a wide range of desirable modifications of any shop-department plan because of enormous differences in nature and tonnage of plant output. Hence there is more opportunity for fruitful discussion of suitable arrangement of staff divisions than there is of line departments.

A foundry such as the author has been considering is one that, so far as the company officials are concerned, is self-contained; that is, one operated as a single unit, and not one of several foundries in a consolidation.

Branch-Plant Management

Obviously where several plants are owned by one company, procedures must be adopted for a discriminating degree of authority given to local directing representatives. The author's experience indicates that the resident manager should be given reasonable freedom in prescribing how specified results may be obtained. He should have no restrictions placed on the selection of his subordinates. He should have a voice in decisions regarding any operating procedures laid down to be strictly observed. His judgment ought to be followed to a large extent as to policies governing relations with workingmen, because of his familiarity with local conditions. The man in charge of a plant detached from headquarters occasionally occupies an unpleasant position, the difficulties of which are inadequately appreciated by his superiors.

Policies Governing Staff Departments

Some details can appropriately be mentioned regarding the manner in which the staff departments should function, although the nature of the particular foundry's business has much to do with such matters. It is possible to outline some of the major considerations, from a general standpoint.

Sales Department. No sales department should try regularly to secure orders for parts that will be entirely satisfactory when produced from weaker and less expensive metals. The fitness of the part for the use intended should always be carefully considered. Any other policy, if carried sufficiently far, will react unfavorably on the management responsible, and in the end will benefit nobody.

It is necessary, in a far-sighted merchandising policy, to have the closest coöperation between sales and operating officials. The latter, because of early training and present responsibilities, have their practical sense well developed. They often have sound ideas as to the ultimate result to the consumer and to the steel foundry, of efforts to secure business in certain fields.

The sales department can usefully employ a man, and sometimes several, much of whose time can be devoted to "service." Each of them should be thoroughly familiar with the way castings are made, and therefore be able to explain to a consumer the reason for any defects regarding which he may complain. Sometimes a consumer's attitude toward an imperfect product is completely changed after learning of the numerous factors involved and the vast amount of effort expended in doing a perfect job.

Accounting Department. The accounting department of any relatively large plant sometimes acquires systems involving costly records that may continue to cause expense long after they serve useful purposes. This is liable occasionally to occur without the realization of the management or the men supposed to be aided by examination of the data.

It seems advisable for an executive periodically to make a comprehensive analysis of all clerical records, and regulate their continuance by their future utility. Campaigns to eliminate superfluous records and to dispense with unnecessary clerical help have in certain foundries materially reduced overhead expense without imposing a handicap of any kind.

Purchasing Department. There are some buyers to whom the management gives more latitude in the selection of materials on a price basis than is economical. Men responsible for mechanical operations are entitled to the full consideration of their views regarding the suitability of commodities and equipment.

One large steel-casting plant whose purchasing department was conducted very efficiently, apparently permitted all selections to be made by the purchasing agent, while in reality the procedure was far different. The buyer was guided strictly by the preferences of the operating department as given to him after a study of all proposals, gaged in degree of desirability expressed, whenever possible, in definite terms. For example, if the foundry needed a lathe for its maintenance department, the operating head requested the purchasing agent to secure proposals from sources indicated by the plant. A careful examination of the good points of each tool offered was made, followed by a report to the purchasing department indicating first, second, and third choices and the extent to which each choice was justified in first cost according to the judgment of the plant. This scheme was followed with perfect satisfaction to the two departments concerned.

Cost Department. The steel-foundry industry has undoubtedly needed improved methods of cost accounting more than have numerous other industries which, because of their product, more easily permit the installation of a good cost system. The jobbing foundry presents a difficult problem in the adoption of many cost-finding schemes that can be satisfactorily applied elsewhere. The principal element that must be kept in mind in applying any system to a steel foundry is related to the sense of proportion. Some schemes are too elaborate to justify the expense of determining actual costs in view of the returns on a small order for castings.

In the foundry making a wide variety of castings on orders, each of which frequently calls for very few pieces, the general procedure in attempting to solve the cost problem is to classify by weight. The weight of a casting generally has a great influence on its cost of production, and consequently on its proper selling price. Other factors, however, make weight classification alone very deceptive. It is unfortunate that up to the present time many steel founders have adhered to the practice of classifying foundry costs by weight divisions. This has handicapped the industry and all served by it.

There has been considerable discussion of more effective and thoroughly practical plans of ascertaining costs in the steel foundry. A paper presented by W. J. Corbett at the convention of the American Foundrymen's Association in Milwaukee, in October, 1924, occasioned a large amount of constructive comment. A study of the scheme outlined in that paper is suggested to those particularly interested in this subject.

Drafting Department. Every steel foundry doing jobbing work must frequently calculate estimated weights from customers' drawings. This is properly the draftman's job, and sometimes requires much time. Many inquiries are received for prices on castings, the weights of which are not indicated on the customer's drawings or requests for quotations. Engineers associated with companies consuming steel castings can do much to help themselves and assist the foundry by showing the estimated or actual weights of castings on all drawings. The merchandising department is unable to intelligently establish all important factors relating to the appropriate selling price until the weights of the castings are definitely known or estimated.

Failure of the customer to furnish weights of castings previously made at another foundry is generally due to oversight by the purchasing agent. The omission of estimated weights on a drawing for a new casting is frequently an unjustified error, due to lack of understanding of weight significance to the foundryman. In most cases the engineer is required to estimate the weights of new castings in order to ascertain the probable cost of the equipment of which the castings are to be parts. Better coöperation between purchaser and consumer along this line will assist the prompt receipt of quotations in closer conformity with production costs.

Order or Schedule Department. Some shops have more or less novel and effective adaptations of the general plan for conducting this small but important division. One consists in a record of the number of delivery promises kept during each month. The final percentages are scrutinized with care by the management. Such a plan probably brings the best judgment to bear on the customer's request for information as to shipment.

In some foundries daily meetings are held, presided over by the head of the order department, and attended by every shop foreman concerned in the execution of orders for castings. All requests for delivery promises are there considered, and information is exchanged regarding the elements involved in delivery. The plan undoubtedly has some advantages. Its application in any foundry should be considered with reference to the practicability of assembling all interested persons at one time, thus simultaneously removing from their departments the men concerned.

Research Department. The research, or experimental, department should be a very active one, although its personnel may sometimes be a single individual. When one man is selected to direct all of the investigations, provision must be made for periodically giving him assistance. The man actively in charge of research should report to the plant manager and be in close contact with him. A manager generally has a much more practical idea of results that may come from investigations than has an investigator, who because of his regular occupation may be absorbed in a problem that appeals more to the imagination than is justified by its probable useful application.

The research engineer, except in rare cases taking little of his time, should not have responsibilities relating to production routine. The smallest steel foundry gives ample opportunity for one good man to spend all his efforts on technical investigations that will improve quality or reduce costs.

Metallurgical Department. The metallurgical department of a well-organized steel foundry should be the source of general instructions to those in charge of melting and heat treatment. It should scrutinize current literature relating to these operations and to all matters connected with tests of significance to the industry. The company should keep informed of actual or needed developments in formulating and revising specifications for its product.

A well-qualified metallurgist is a highly valuable member of the organization. His duties should include much more than the general supervision of routine furnace operations, physical tests, and chemical analyses. He should collaborate with the research engineer, and like him should have a practical point of view to balance his scientific training.

Inspection Department. In the regulation of a systematized inspection department, much depends on the suitability of the man in charge. His task is daily associated with as many complexities and demands for the exercise of good judgment as is that of the man in charge of the order department. This individual probably should have more disposition to act on his own judgment alone than is advisable in the case of many other subordinates in the steel foundry, in order to successfully and conscientiously discharge the duties outlined, with regard for the customer's interests. Definite-

ness of conviction should be preceded by much practical knowledge of foundry conditions and by considerable information regarding general industrial application.

A casting may be suitable from the standpoint of surface appearance, but contain vital defects in the interior. The chief inspector should have facilities for ascertaining the soundness of sections, to remove all doubt before the product is delivered. This may be satisfactorily accomplished by systematically destroying representative castings by machining operations that disclose the interior. The most skilful foundrymen cannot be trusted always to produce castings free from shrinkage cavities and other serious defects, unless aided by observing samples cut into pieces. When this discloses an undesirable condition, the experienced foundryman can modify his practice to overcome the defect.

The use of templets and gages by the chief inspector's subordinates is made very satisfactory by carefully checking these with master gages in the execution of production jobs. The importance of this is not always realized. Gages are sometimes zealously used, but are ineffective because of wear. If the nature of the order for castings makes master gages impracticable, there should be periodic checking of regular gages from drawings.

Compensation of Workmen

In large foundries it is advisable, in the author's opinion, for the plant manager to have a man who has had considerable experience in the operating departments, who has tact and cleverness, and who combines carefulness with proper consideration for the mutual interests of the men and the management, to be continuously engaged in the study of compensation to workmen doing piece work, task work, and day work.

Too many employers have in the past pinned their faith to the installation of a piece-work plan as the cure for their troubles with workers. Much thought should be given to the operation of a piece-work scheme. Probably in no other industrial enterprise is this more true than in the case of the jobbing foundry, because of the great variety and short duration of the tasks, some of which are of such nature as to preclude satisfactory piece-work rates.

There are many more or less ingenious plans for applying piece-work principles to steel-foundry operations. Some guarantee a minimum daily wage to the man, and give him in addition a reasonable sum for a stated amount over the established number of tasks. Certain compensation plans go further, and provide for increasingly greater piece-work rates as the speed of the man advances beyond the average rapidity of execution. Some plants pay bonuses semi-monthly or monthly for constant attendance during designated working hours. Some production jobs that have been running in foundries for long periods can profitably have applied to them bonus schemes, based on a minimum percentage of defectives.

Piece-work compensation of molders has in some foundries been advantageously developed by means of time studies to show the proper relative significance of every detail of a molder's task. Such a scheme employs a unit system for calculating equitable rates, by indicating the time required for each step in making a complete mold. Carefully planned in a spirit of fairness it possesses important advantages, particularly in establishing without delay suitable rates for new jobs, and in convincing molders, as the result of experience, that they are getting a square deal.

It is well to daily advise men who do piece work and who are paid bonuses for low percentages of defectives, regarding the results of their work. Such advice is sometimes given in the form of posted figures on the man's floor or bench where he and his associates can examine them. This occasionally produces a wholesome rivalry that is more stimulating than the increased wages.

It is appropriate to say in passing that there are certain operations in the steel foundry where piece work on a tonnage or other basis should not prevail, for reasons that relate to quality.

Given suitable equipment and the proper amount of direction, experienced molders will do satisfactory work at a stated price per mold. In this and similar foundry operations there is not the danger of sacrificing quality for quantity that exists, for example, in melting steel, in heat treatment, or in welding castings. Men who are paid for quantity production in the operations just mentioned and in similar ones are prone to be influenced in their work in a way to detract from the quality desired by the management.

Where piece work cannot be effectively employed, a task-work plan is sometimes advisable. Much thought should be given this arrangement as applied to a crew of men, to prevent abuse. The inherent weakness of the scheme as ordinarily employed lies in compensating each man in the gang on the same basis, despite the fact that some individuals may be much faster workmen than others. The larger the crew, the greater will be the difference in the work done by each person, with resulting justified dissatisfaction.

Compensation of Foremen

The compensation of those actually responsible for directing shop operation, beginning with the superintendent and including such men as core foremen and cleaning-room foremen, requires as careful consideration as does the compensation of the workmen. Many steel foundries supplement the monthly salaries given these men by bonuses for individual meritorious achievement. Without doubt some sort of bonus plan is desirable for the payment of foremen, provided fundamental considerations are satisfied. These include, first, the payment of a salary fully in keeping with the routine responsibilities carried, and with local conditions (if these in any degree establish a rate for a similar occupation); secondly, a bonus that will reward the faithful and effective individual liberally for signal service performed; thirdly, a bonus scheme, all details of which can be fully explained and completely understood by the men to whom it is applied; and fourthly, a plan which, in justice to the management, is based partly on the general financial showing of the plant or on factors that cannot be dissociated from it, to prevent in hard times the payment of compensations on a scale out of proportion to prevailing circumstances.

A bonus plan for foremen should therefore be rather comprehensive and be developed with ample consideration to operating profits and the man's part in creating them. When substantial bonuses are earned by a few principal subordinates at times when the company's operations as a whole are not profitable, payment should be made gracefully as long as it is made at all, so that the good effect of the reward on the recipient will not be nullified.

Any plan for paying bonuses to principal shop subordinates should provide in an auxiliary way for each of a number of valuable men performing duties not directly related to production routine. If such men are not included in the bonus plan, they invariably feel that circumstances have unfairly operated to prevent their earning appropriate compensations for the fidelity and skill with which they may perform allotted tasks. It is often difficult to establish a special compensation plan for each of the men in this general class. The management should so solve the problem as to convince employees that they will be specially rewarded for particularly meritorious execution of duties.

Conclusion

If this outline of the author's observations and opinions regarding some phases of steel-foundry management should give engineers engaged in other activities a clearer idea of the details of steel-casting manufacture, the result may be closer coöperation between some who make, and others who use, the product of this important factor in modern civilization now capable of supplying 2,000,000 tons of castings annually, from a total of 350 steel foundries in the United States. This giant of industry has acquired all of its growth in America during less than 60 years. The remarkable development thus indicated has been accompanied by a progressive increase of technical and commercial problems requiring solution by the steel-foundry manager.

Discussion

REPLYING to a question raised by A. B. Segur,[1] chairman of the management session at which Mr. Bull's paper was presented, W. J. Callaghan[2] said that at the plant of the Allis-Chalmers Mfg. Co. the inspector of castings reported to the general works manager, and that this arrangement had been found satisfactory. A. E. Harrison[3] corroborated this, and said that if anything was found

[1] Member of Executive Committee, Management Division, Chicago, Ill.
[2] Allis-Chalmers Mfg. Co., Milwaukee, Wis.
[3] Allis-Chalmers Mfg. Co., Milwaukee, Wis.

wrong, the inspector was supposed to settle it with the head of the engineering department.

C. J. Siegle[1] said that in case of a supposed defect the inspector should consult the foundryman that poured the casting, and if nothing abnormal had happened, should take the matter up with the management and the engineering department. If the casting was poured properly, the foundryman should have his say in the matter of rejecting it as against the inspector. No one could look inside a casting and condemn it unless he knew how it had been poured.

E. Standfuss[2] said that he had never favored having an inspection system under the sales department unless the latter was in charge of the management of the business. The best policy was to make the inspection a unit of the operating department, all inspectors reporting to the works management. Questions arose at times that affected sales, engineering, and accounting, and the management should make the final decision.

A. W. Gregg[3] said that he agreed with the general principles laid down by the author, but disagreed with him in certain details, namely, the order or schedule, the metallurgical and the construction sections. He believed that the work of all of these was the function of the operating department. In his company's plant the chief inspector reported to the works manager. The man that passed on the quality of castings should have no interest whatever in the tonnage produced or its cost.

N. Singh[4] asked the author's opinion on the staff organization of a foundry, on the trend of modern management in foundries, and on the post-graduate training students should receive before they entered foundry work.

The author, in closing, said that his remarks regarding inspection had evidently not been clearly understood by some of those taking part in the discussion. He had pointed out that in his own opinion the inspection ought to be under a company executive and not necessarily that it ought to be under the sales department.

In his opinion, one of the functions of the right kind of a chief inspector was to see all heats poured. He had once put in several years at the job of inspecting steel castings and one of his duties had been to see every heat poured on the day shift and to have an assistant to do the same thing at night.

He believed with Mr. Gregg that the head of the operating department ought to in every sense be a company executive, and in laying stress on the fact that company executives ought to have the direction of certain departments, he had not meant that the head of the operating department should have no direction of those matters. His conception of an ideally constituted steel foundry was one in which a company executive of commanding relative position was the head of the operating department.

So far as the special training needed to equip young men to hold executive positions in the foundry was concerned, the author thought it would be very difficult for any one to be specific and say that a training along any special line was best calculated to produce the best type of executive. He believed the question was related more to aggressive personality than to any other one thing and that the best kind of foundry executives, or the best kind of industrial executives generally, were those men who had been blessed by nature with a pleasing personality combined with the necessary amount of force and aggressiveness that enabled them to exercise it in an effective way. No other asset was so valuable in the direction of a foundry, and perhaps in any kind of an industrial enterprise.

A reasonable knowledge of accounting, as well as a broad knowledge of engineering work and considerable knowledge of metallurgical work and of merchandising methods, were all highly valuable to a man after he had finally obtained a managerial position as the head of any large foundry organization. But if a man was gifted by nature with the kind of a personality that would draw men to him and induce men to carry out his instructions, he would probably be better equipped than if he was particularly proficient along any other one of those differentiated lines.

Castings and Forgings

Methods of Examining Steel Castings by X-Rays for Defects—Castings and Forgings from Aluminum and Its Light Alloys—Avoidance of Defects in Large Steel Forgings

AT THE Materials and Machine Shop Practice Sessions of the Spring Meeting in Milwaukee, in May, three papers were presented dealing with the above-mentioned subjects: namely, The X-Ray Examination of Steel, by I. E. Moultrop[5] and E. W. Norris,[6] which described the use of X-ray apparatus in examining steel castings for defects, with particular reference to those used in the high-pressure-steam station of the Edison Illuminating Company's station at Weymouth, Mass., and discussed some examples of work in which flaws were discovered; Aluminum and Its Light Alloys, by Robert L. Streeter[7] and P. V. Faragher,[8] which gave data on the mechanical properties of alloys for sand, permanent-mold, and die castings, wrought aluminum, and high-strength alloys and forgings therefrom; and Defects in Large Forgings, by J. Fletcher Harper,[9] which enumerated some of the common ones encountered in large steel forgings, briefly explained their causes, and described methods used to insure uniform and homogeneous material. These papers, all of which were published in Part Two of the May issue of MECHANICAL ENGINEERING, were the subjects of extended discussion, and a summary of the more important points brought out appears below.

[1] Harnischfeger Corporation, Hercules Plant, Milwaukee, Wis.
[2] Milwaukee, Wis.
[3] Bucyrus Co., South Milwaukee, Wis.
[4] Professor of Business Administration, Marquette University, Milwaukee, Wis. Mem. A.S.M.E.
[5] Assistant Superintendent of Construction Bureau, The Edison Electric Illuminating Co. of Boston, Boston, Mass. Mem. A.S.M.E.
[6] Engineer, Mechanical Division, Stone & Webster, Inc., Boston, Mass. Mem. A.S.M.E.
[7] Vice-President, The United States Aluminum Co., Pittsburgh, Pa. Mem. A.S.M.E.
[8] Technical Direction Bureau, Aluminum Co. of America, Pittsburgh, Pa.
[9] Research Engineer, Allis-Chalmers Mfg., Co. Milwaukee, Wis.

X-RAY EXAMINATION OF STEEL CASTINGS

John H. Hall[1] wrote that as a foundryman he was glad to see that the engineers applying the X-ray tests were disposed to exercise excellent judgment in accepting castings which were not absolutely sound, provided the unsoundness was so located as not to be really harmful to the casting. Foundrymen as a body were naturally greatly interested in the development of X-ray examination and saw in it a means of greatly improving their practice; but at the same time they saw a danger in it in the hands of purchasers of castings who were unfamiliar with foundry practice and might be disposed to demand 100 per cent perfection in cases where such perfect work was not necessary or expected.

F. H. Morehead[2] wrote that he believed the greatest benefit to be derived from the apparatus described in the paper was in the development field, and that its greatest value would be on products which were made in quantity rather than on specific castings for a particular use. If a given casting was to be manufactured in quantity it was possible to give to that casting an intensive study and to develop equipment for its production which would insure uniformity of product. Such a study and such an equipment were out of the question when relatively few castings were to be produced. There was no doubt, however, that the X-ray was of value as an inspection means on important castings in extremely hazardous locations.

The authors intimated that castings containing defects of less magnitude than from 10 to 20 per cent of the section were approved and, under certain conditions, considered suitable for use. This

[1] Metallurgical Engineer, Taylor-Wharton Iron & Steel Co., High Bridge, N. J.
[2] Assistant Chief Engineer, Walworth Mfg. Co., Boston, Mass. Assoc-Mem. A.S.M.E.

was probably justifiable in the inspection of an occasional casting intended for a particular duty. When, however, the X-ray was used in its widest application for the development of a technique, the cause of even these small defects must be located and eliminated.

As to cavities caused by gas from various sources, Mr. Morehead wrote that the source of the gas causing the cavities might be rather definitely fixed by consideration of (1) its location in the section, and (2) the appearance of the inner wall of the cavity upon sectioning the casting. Reducing gases formed cavities with bright metallic interior walls, while oxidizing gases formed cavities with oxidized walls.

The X-ray examination of castings, he wrote, would never become

Fig. 1 Photomicrograph Showing Dendritic Structure in a Steel Casting Caused by Very High Pouring Temperature and Which Cannot be Eliminated in the Heat Treatment, × 100

a widely used method of inspection. The expense of the equipment and its cost of operation seemed to eliminate it as a factor in this field. As a means, however, of studying intensively a given repetitive operation it was unexcelled.

A. K. Fischer[1] wrote that the value of the examination by X-ray had been established beyond doubt for certain requirements, always provided that the men analyzing the X-ray pictures used good judgment. Care should be taken that they were not too severe in their desire to prevent castings being used which had passed the X-ray examination but might prove defective later on under actual steam and water tests.

The X-ray examination should be used essentially in two cases: first, for castings of which only a *few* were to be made but which had to stand an exceptionally high pressure, and where the question of time and money could be discarded, the main object being to get castings which would stand the high pressure; and, secondly, for castings of which a great quantity was going to be made and where it was advisable to investigate a few castings in every possible way before quantity production was started. The progress of the art would no doubt in the course of time make the process of X-ray examination less costly, and obviate the loss of time now involved, thus making it possible for the large foundry to acquire an X-ray outfit.

V. T. Malcolm[2] and A. Sproat[3] submitted a joint written discussion in which they said in regard to the statement in the first paragraph of the paper that improvement in quality of material must be made and that physical properties must be better, that an alloy steel for steel valve castings had been developed possessing physical properties much higher in value than those of ordinary cast steel.

The authors had shown pictures of shrinkage cavities which were the most prolific source of foundry defects and were due mainly to improper feeding of castings. The explanation of the cause of shrinkage cavities was, in the writers' opinion, as follows:

The difference between the density of crystals and that of liquid metal might cause indirectly porosity. X-ray and macroscopic examination showed the existence of voids or cavities due to metal being poured at incorrect temperature, the metal not being fluid enough to clean itself. In addition to the defects noted, zones of weakness were caused by this interior porosity, which of course reduced the safety factor in the castings.

Cracks in steel-casting practice were readily understood and presented no difficulty if care was taken and if the casting was designed correctly, and with the proper placing of fillets so that thick and thin sections did not meet sharply. A second cause of cracks was improper chemical constituents such as oxides of iron and manganese, which would cause a concentration of impurities along the grain boundaries and cause the steel to crack later in the heat-treating process, giving rise to a steel of poor quality. This condition was harmful and could readily be overcome by the proper deoxidation of metal in the furnace.

The photograph of dendritic structure shown in the authors' paper was typical of a high casting temperature and incorrect heat treatment. This structure had been the cause of a number of failures in pipe fittings and was a harmful condition but might be eliminated by careful heat treatment.

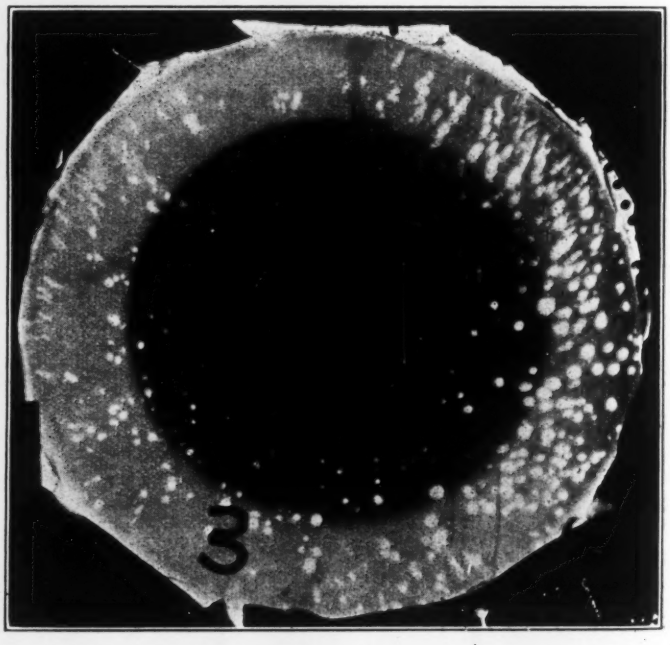

Fig. 2 Radiograph of Experimental Steel Casting Showing the Result of Improperly Deoxidized Metal. (Reproduced Half-Size)

Fig. 1 showed a very bad structure of a failed fitting that had come to the writers' attention and was not heat-treated. The structure noted was serious because it appeared only in certain portions of the casting and showed planes of weakness, for the reason that any impurities in the steel would collect between the chill dendrites of the steel. These conditions might be eliminated where pouring temperatures were under technical control.

Rarely was metal the cause of interior porosity or defects, but some time previously the writers had claimed that metal, if improperly made, could be a source of defects, and bad ones at that. In an endeavor to prove their case, they had purposely made a small heat of effervescent steel or steel that was improperly deoxidized, with the results shown in Fig. 2. After careful study they had come to the following conclusions:

Effervescence in steel might be defined as the escape of gases,

[1] President, Schutte & Koerting Co., Philadelphia, Pa. Mem. A.S.M.E.

[2] Metallurgical Engineer, The Chapman Valve Mfg. Co., Indian Orchard, Mass.

[3] Superintendent of Foundries, The Chapman Valve Mfg. Co., Indian Orchard, Mass.

mostly carbon monoxide, in myriads of bubbles, from the molten metal and their escape from the metal tended to keep it in violent motion, with a churning effect as the metal froze from sides to center. These bubbles threw off brilliant sparks from the liquid steel, which diminished as the steel froze.

Effervescent steel would cause a "kick back" in the sink heads, giving rise to the so-called "cauliflower" head.

The blowholes or cavities noted in the radiograph were due to the presence of gas; the oblong ones were caused by the improperly deoxidized metal and the spherical ones by steam generated from the mold at the time of pouring.

The oblong-shaped blowholes were caused by chemical reaction taking place in the metal due to its incomplete deoxidation and were silvery white and contained a black deposit which, upon chemical analysis, was found to be iron oxide together with some silica, while the metal adjacent contained considerable so-called "dirt," which in reality was oxides. The bubbles of these oxides were very minute and bubbles of carbon monoxide were formed around them which did not rise through the molten metal and gave rise to sponginess in the casting.

Summing up as to foundry defects, the writers said that such defects as entrapped gas or blowholes, sand and dirt inclusions, might be eliminated entirely by close study and careful attention to the details of foundry practice, and that pipes, cracks, and cavities could be controlled by proper design and knowledge of the castings at hand. They had great faith in what the X-ray had done and would do to insure the integrity of castings made by their company, but one thing of great importance must be remembered, and that was, the examiner of radiographs should be skilled in foundry technique and thoroughly capable of distinguishing between blemishes and defects.

The writers noted with great interest the statement by the authors that steel forgings had proved so reliable in service that routine tests and analyses were considered satisfactory. They were surprised at this statement, as they had been intimately associated for a number of years in the manufacture of forgings, and had had considerable opportunity to investigate failures in service, and they believed this statement needed an answer. From their knowledge of the situation they believed that more actual defects were found in forgings than in steel castings.

The writers were familiar with a number of forging failures, and each and every case had shown that the grain flow dropped off abruptly under the flange; and when forgings were placed in service, fatigue failures resulted. It had been recognized and substantiated by actual experience that the ability of forged steel to withstand stress was a direct function of the grain.

Heat treatment had a great bearing on this condition as well as piping and inclusions in the original ingot, which, when rolled into forging stock, was piped or seamed so as to cause cracks that were not noted in the test bar.

A good, sound alloy-steel casting was often superior to a forging, particularly when the forging operation had been carried out so that flow lines developed planes of weakness. The surprising ability of these castings to replace presumably fine forgings had perhaps been responsible for their introduction lately into the automotive and railroad industries.

John T. Norton[1] wrote telling of radiographic examinations of castings and welded joints at the Massachusetts Institute of Technology. Aside from the opportunity which the X-ray examination gave of determining blowholes, seams, cracks, sand inclusions, etc., there was another adaptation which was becoming of great importance, namely, that of examining metals for their crystal structure. Apparently many of the physical properties of metals, such as ductility and hardness, were closely related to the arrangement of the atoms in the structure of the metal, and the X-ray method of crystal-structure examination gave another means of studying these properties. The effect of cold work and heat treatment had been studied by this method, which also lent itself particularly well to the problems which concerned the structure of alloys.

F. C. Langenberg[2] and H. H. Lester[2] contributed a joint written discussion in which they said that there had been in the past and still was in some places a prejudice against steel castings. This feeling had been due to uncertainty as to defects inside the metal that might cause failure. Notwithstanding this uncertainty, steel castings must be used, because of their superior strength. But to eliminate the defects that had given them their bad reputation, some method of examination was needed that would reveal conditions within the metal. The X-ray test seemed to meet this condition. Sections up to $3\frac{1}{2}$ in. in thickness could now be examined with comparative ease, and it was probable that sections as thick as 7 or 8 in. could be examined within a year or two.

There were three principal applications of these tests that interested the structural engineer and the foundryman, namely, (1) the elimination of defective castings by more searching inspection tests; (2) the study of casting defects to the end that, through a more complete knowledge of the defects and their causes, they might be eliminated; and (3) the study of pilot castings to the end that the most economical methods of manufacture might be developed that would give requisite high quality.

The third heading dealt with what was probably the most valuable application of the radiographic method of testing. The development of manufacturing technique involved the attainment of quality in the most economical way. The forced study and successful overcoming of specific defects in one casting trained the foundry engineer and other personnel so that the information gained was reflected in a higher quality, and reduced rejects in other castings that might not be subjected to the X-ray tests. It would be found, however, that where commercially perfect castings were to be obtained, study would be required for each individual casting, but the results of such study would in the end reduce the cost of manufacture in some cases and in others definitely fix such costs and thus give the basis upon which fair selling prices might be figured.

There was a wide interest in the subject throughout this country wherever castings were made, and extensive use was being made of the available facilities at Watertown Arsenal by commercial concerns.

A. E. White,[1] who discussed the paper in person, said that one of the slides shown gave a micrograph of a casting showing dendrites which it was stated had not been removed because of improper heat treatment. It had been his experience that for cast stock it was impossible to eliminate dendrites by heat treatment. If they were present, they could be eliminated by a combination of mechanical work, but he had not succeeded in eliminating dendrites when they were once present by heat treatment alone. Therefore he believed that the casting condition should be so regulated as to keep the dendrites from forming as the metal went from the liquid to the solid state, rather than by attempting to remove them if once formed by heat treatment.

He was looking forward to the development of the X-ray whereby it would be possible to examine the interior of castings with the same degree of accuracy as the outside surface of castings was now examined. He saw no reason why the X-ray should not be used, and with the use of a fluorescent device the casting visually be examined for any imperfections, in order to ascertain their nature if any were present.

It was likewise necessary to differentiate rather carefully between the nature of the defects. The defects which were circular probably were not nearly as serious as those which were in the nature of angular obstructions. That type of defect would probably result in the development of the X-ray and fluoroscope more rapidly than would the circular.

Mr. Norris, who presented the paper, said in closing that in it emphasis had been put on the use of X-rays as an inspection method for castings for very severe service. The authors did not wish to imply a doubt that X-rays would probably find their most useful application in the development of foundry practice, because they believed that was by all means the best that could be expected from them. The examination of castings for crystal structure was still almost exclusively a laboratory matter, and had not yet been given a practical application in engineering work.

Mr. Malcolm had shown some very excellent slides and spoken about the effect of forging. Mr. Norris thought that perhaps in

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[2] Watertown Arsenal, Watertown, Mass.

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the paper the authors had not been quite clear when they said they considered forgings sufficiently reliable not to require X-ray examination. They considered that the parts where forgings figured in their apparatus were sufficiently reliable; in other words, if the forgings should fail no serious result would be expected, while it would be a very serious matter if the parts made of castings should fail.

Mr. Fischer had spoken of the hydrostatic testing. The authors believed this was a very important adjunct to the X-ray examination since, as indicated by Professor White, if the flaws shown in castings were of a rounded form which did not show a tendency to increase during use, the use of the hydrostatic test was indicated to prove the strength of the casting. These tests should be combined with the X-ray to indicate the yield point under service conditions. The hydrostatic test without X-ray examination did not afford a conclusive test, because castings might contain concealed flaws which were likely to increase during use.

As to the use of the fluorescent screen, he feared that this would be postponed for a long time, because there were two serious difficulties. The rays penetrating the castings were so faint that it took a very prolonged exposure to photograph a part in order for it to register. Also, when these rays were passed through a heavy body the necessary radiation was so intense that it would probably be exceedingly dangerous for any human being to be in the same room with it.

Aluminum and Its Light Alloys

J. A. Capp,[1] in discussing the paper by Messrs. Streeter and Faragher, wrote that the properties of commercially made parts had often been so disappointing when compared with expectations based on the data supplied only on the basis of laboratory experimentation, that the use of aluminum alloys had been abandoned. Had the expectations been based on properties of metal parts commercially available, many of these abandoned applications of aluminum alloys might have proved entirely desirable.

Designers had long been accustomed to the ordinary metals, which were very largely iron or copper alloys. They had known by experience just what they could depend upon when using these metals and how they could best be applied, and particularly, what must be avoided if success was to be obtained. When considering aluminum alloys, however, the consideration had frequently been largely, if not solely, on the basis of substitution, and failure had resulted. The knowledge of and experience with aluminum alloys had not generally been developed to the point where the design was made and proportioned on the basis of these alloys with their known advantages and disadvantages.

H. C. Knerr[2] wrote that he could from personal experience confirm a large part of the data presented in the paper, and as the result of several years of contact with the source of the information, did not hesitate to accept the whole as conservative and reliable. A word of caution as to the resistance to corrosion of aluminum and its light alloys might not be out of place. Corrosion resistance was a relative term. To say that these materials were, in general, resistant to corrosion was true, and some were more resistant than others, but it did not mean that any of them might be directly exposed to the action of moisture for an indefinite period without harm. Where prolonged exposure to moisture, especially salt water, was necessary, protective coatings should be applied. The resistance to corrosion of alloys of the duralumin type was greatly affected by the heat treatment they had received.

D. J. McAdam, Jr.,[3] wrote that it seemed unfortunate to one familiar with the reports of the Alloys Research Committee of the British Institution of Mechanical Engineers that the authors dismissed the aluminum-nickel alloys with a mere mention. They mentioned the fact that the aluminum-zinc alloys decreased rapidly in strength with increase of temperature, but omitted to mention that the Committee in their search for aluminum alloys that would retain most of their strength at elevated temperatures had obtained best results with aluminum-nickel alloys. The Alloys Research Committee had found that aluminum-copper alloys lost their strength rather rapidly with increase in temperature. For example, the alloy containing 12 per cent copper decreased in tensile strength from about 20,000 to 13,000 lb. per sq. in. with an increase in temperature to 200 deg. cent. which was the important temperature for airplane pistons.

In the authors' description of high-strength alloys they made the statement that the physical properties of these alloys in the heat-treated temper were comparable with those of mild steel. They referred to "the advantages of a metal having the strength of mild steel with a weight approximately two-fifths as great." Such statements, however, were somewhat misleading. These alloys were recommended for and used in structural parts such as angles, channels, and plates, and in machinery parts such as connecting rods. The value of the alloys for such service depended not on tensile strength, but on either elastic limit or endurance limit. Although the tensile strength of duralumin was comparable with that of mild steel, its elastic limit was about two-thirds that of mild steel and its endurance limit less than half that of mild steel.

When heat-treated duralumin was to be subjected in service to not more than about 8,000,000 cycles of a range of stress, the elastic limit was the important property. When, however, a machinery part in service was to be subjected to more than 8,000,000 cycles of stress, the endurance limit was the important property. The endurance limits of heat-treated and annealed duralumin, were about 12,000 and 11,000 lb. per sq. in., respectively. Below these stresses the material would endure many hundred million reversals of stress. The endurance limit of mild steel was 25,000 to 30,000 lb. per sq. in.

The specific endurance (endurance limit ÷ specific gravity) of duralumin for repeated tension-compression was barely equal to that of annealed mild steel. The specific endurance of duralumin for repeated bend or torsion was about 50 per cent higher than that of mild steel. The substitution of duralumin for mild steel, therefore, would result in no saving of weight of a machinery part for repeated tension-compression, but would result in a saving of about one-third in weight of a machinery part for repeated bend or torsion. The specific endurance of some magnesium alloys was about 70 per cent higher than that of duralumin.

As the authors said, there was great need for further research for high-strength alloys. One of the greatest needs was for an alloy with a higher ratio of endurance limit to tensile strength (endurance ratio). The endurance ratio of heat-treated duralumin was less than 0.25, whereas the endurance ratio of steel was about 0.50, and that of many alloys of nickel and of copper about 0.40.

The authors did not discuss one of the chief advantages that might be obtained by substituting high-strength aluminum alloys for steel in structural or machinery parts. This advantage was increase in stiffness. For bend or torsion, duralumin and steel parts would be of equal stiffness when their respective areas of cross-section were about as $1^3/_4$ to 1. Under these conditions the duralumin part would be about 0.7 as heavy as the steel part. It was possible, therefore, by substituting aluminum alloy for steel in a machinery part for bend or torsion to reduce the weight about 30 per cent without decreasing the stiffness. The elastic or endurance strength, of the aluminum alloy for this purpose must be about 45 per cent that of steel. The elastic strength, but not the endurance strength, of duralumin would be great enough to permit its substitution for mild steel under such conditions. It was evident, therefore, that any further reduction in weight of structures or machines due to development of new aluminum alloys of increased elastic or endurance strength would be accomplished at the expense of stiffness. Since the modulus of elasticity depended chiefly on chemical composition, it could not be increased without an accompanying increase in specific gravity.

J. B. Johnson[1] wrote that as far as the casting alloys were concerned, their use in airplanes and airplane engines was rapidly decreasing except for alloys Nos. 195 and 196. The aluminum-silicon alloys had been tried on several occasions, but had been found to be unsatisfactory on account of the low proportional limit. It had been found that a low stress would cause permanent deformation of the 13 per cent silicon alloy (modified), and if the load was not removed the yielding would continue.

One casting alloy which had not been listed but which was being

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[3] Metallurgist, U. S. Naval Engineering Experiment Station, Annapolis, Md. Discussion published by permission of the Secretary of the Navy.

[1] Chief of Material Section, Air Service, McCook Field, Dayton, Ohio.

used in the more recent types of aircraft engines for pistons, air-cooled cylinder heads, camshaft housings, and miscellaneous castings, was a copper-nickel-magnesium alloy which was originally made in this country under the name of Magnalite. The present Army Air Service specification was as follows: Copper, 3.75–4.50; nickel, 1.75–2.25; magnesium, 1.25–1.75; aluminum, remainder except for a small amount of allowable impurities. This alloy was susceptible of heat treatment and developed a tensile strength of 32,000 lb. per sq. in. and a Brinell hardness of 90 with a 500-kg. load. It had one valuable property for internal-combustion-engine work, namely, it tended to hold its strength to a greater degree than other alloys when heated to temperatures of 500–700 deg. fahr. and air-cooled.

The strong wrought alloys of aluminum had been used quite extensively in airplane designs in the form of sheet, tube, and bar. Their use had been somewhat curtailed on account of the greater cost of fabrication compared to other materials. Welding was not satisfactory when the joint was part of the primary structure, since the weld had only the strength of the cast metal and no practical method of increasing this strength had been developed; therefore it was necessary to resort to riveting and pinning. There was no doubt, however, that a saving in weight could be effected, and this saving had amounted to approximately 50 per cent in a recent design.

Mr. Faragher, in opening the oral discussion, said that in preparing the paper the authors had recognized that they did not have everything that the designing engineer might like to use. They had not included a great many tests which they had made in the course of experimental work, but had stated the properties that the designer might be sure of obtaining every day in the week from commercial material.

They had experimented with the alloy alluded to by both Mr. McAdam and Mr. Johnson, and had found that it did not possess properties superior to those of alloys with which they had had experience and which they were commercially manufacturing. Some commercial castings had been produced from this alloy in the foundries of their company, and at some future time data would be available for this alloy that would be comparable with the other data contained in the paper. It might be mentioned that the Technical Direction Bureau of the Aluminum Company was making a very exhaustive study of the mechanical properties of aluminum alloys at all temperatures up to nearly the melting point. Those results would be published when completed and in shape for presentation.

They were also making an extensive study of the fatigue properties of aluminum alloys, because they recognized that the tensile strength and yield point alone were not sufficient data for the present-day designing engineer.

The statement made relative to the welding of the high-strength alloys which Mr. Johnson had made was correct. These alloys could be welded, but in making the weld a cast material was introduced at the weld which prevented the welded section from having the properties of heat-treated material.

As to resistance to corrosion, aluminum possessed rather superior properties. Certain of the alloys were less resistant than others, and practically all of them less resistant than the pure metal.

In dealing with the high-tensile-strength alloys, it was necessary to take account of the fact that the resistance to corrosion varied with the nature of the heat treatment. Many of the complaints as to the corrosion of duralumin-type alloys had been explained when samples were tested and it had been found that the material had not been heat treated to develop the maximum physical properties.

In reply to a question asked by J. D. Suter,[1] Mr. Streeter said that considerable progress had been made in correcting porosity in alloys which were being used at the present time for die castings. They had succeeded in making castings for low-pressure work, with thin walls, in some cases as thin as $^1/_{16}$ in., with the casting maximum dimensions possibly 10 in. and 12 in. and a weight of three or four pounds.

Mr. Faragher added that the weakness of the silicon alloy had been mentioned by Mr. Johnson, namely, the low ratio of yield point to ultimate tensile strength; but the superior quality of that alloy was that it did give low porosity, and that it could be used for pressure castings. The tendency to draw between heavy and light sections was perhaps less in that alloy than any other alloy. In addition, he might mention that Mr. Johnson in his laboratory at McCook Field had been working on a casing alloy containing both copper and silicon, and while it was not yet a commercial material, it had been found to possess many of the superior casting qualities of the silicon alloys and at the same time the higher yield point of the copper alloys.

E. W. Norris[1] said that his company had had occasion to use pure aluminum for disks in return valves for low-pressure steam, and asked regarding the limiting temperatures that could be used.

Mr. Faragher, in replying, said that all of the high-tensile alloys which were susceptible to heat treatment were also susceptible to artificial aging at elevated temperatures. Briefly, the tensile strength would increase for a certain period of time, would pass the maximum, and would then decrease thereto. The elongation would fall off from the start, the rate at which the decrease took place depending upon the temperature in question. When that temperature went up to about 300 deg. fahr. it would be found that this maximum tensile strength was reached in a period of a few days, and the maximum might be around 64,000 lb. per sq. in. for the 17 S duralumin. It would then fall off and after a period of some ninety days continuous heating might be down just under 50,000 lb. per sq. in., with an elongation of approximately 10 per cent in 2 in., and that elongation seemed to persist as that figure was reached. It would persist for the remainder of the ninety days, which happened to be the duration of the tests they had made on this material.

R. H. Kent[2] asked if it was necessary to use a harder metal plug inserted in the metal where there was to be a threaded hole.

In reply, Mr. Faragher stated that there was a tendency for aluminum to seize and that that tendency persisted throughout the alloys, although the harder the alloy the less the tendency. It might be overcome by electroplating the threads. There was a tendency for aluminum to wear, because it was a softer metal, and with high tensions greater precaution had to be taken.

L. G. Howlett[3] stated that his company had been having some difficulty with porosity in die castings and asked if there was any likelihood that the problem of porosity would be solved.

Mr. Faragher, replying, said that in the die-casting process there was no opportunity for feeding the metal. It entered the mold and solidified, and there was no possibility for feeding the casting during the process of solidification. Therefore he did not see how porosity could be prevented, because it appeared to be inherent in the manufacture. The only way to overcome porosity would be to have a metal which had no shrinkage, or a method of handling in which there would be no shrinkage. Practically all of the casting metals he knew of had solidification shrinkage, and since the die-casting process did not permit any feeding, he could hardly see how to overcome porosity in that type.

Mr. Streeter, in closing, said that Mr. Capp had mentioned the question of substituting aluminum for other materials in the design of machine parts. In such cases there should be proper recognition of the different physical characteristics of aluminum, and the necessary engineering principles applied when change was made from one material to another.

In reference to corrosion, for certain uses it was necessary to have an aluminum which was exceptionally pure, and his company had produced aluminum as high as 99.98 per cent in purity. Hydrochloric acid, for instance, would have no appreciable effect on such aluminum for a period of three or four weeks. While the production of metal of this composition was not at present commercial, somewhat lower purity could be supplied for special purposes. *Concentrated nitric acid had no effect, but diluted had more effect than the concentrated. Coal gas also had no effect on the pure aluminum.

Not long ago he had examined some aluminum roofing that had been on a factory building in the Pittsburgh district for twenty-two years and found no appreciable deterioration. The side next to the roof was nearly as bright as on the day it was laid. He had also

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[3] Chicago Aluminum Co., Chicago, Ill.

recently examined some aluminum transmission cables that had been suspended in the air for about eighteen years. The outside strands were black and discolored, but the inner strands were as bright as the day they were fabricated.

Defects of Large Forgings

T. D. Lynch,[1] in his discussion of Mr. Harper's paper, wrote that it was only after years of actual experience and very careful study that one could judge the seriousness of certain defects and whether or not the stresses involved would permit the safe use of such material in definite design. Even then it was often impossible to determine the definite location of stress concentration. In this day and age engineers were called upon to design for stresses in their materials increased to a maximum. This was made possible for consideration by the steel metallurgist, the steel treater, the specification writer, the testing engineer, all coördinating their efforts with those of the mechanical engineer to produce forgings of a better quality of the same size and of equal quality of a larger size, so that in many cases forgings were in use today that only a few years ago would have been impossible. The larger the forging the greater the complications and the more numerous the problems that must be worked out.

The author had referred to the pouring from more than one ladle as being a questionable practice. If improperly done—yes, but if carefully and judiciously done such a practice made it possible to partly equalize the carbon content in the ingot by pouring a lower-carbon heat into the upper portion of the ingot. This was a problem for the open-hearth metallurgist to work out, and before condemning the practice the facts upon which condemnation was made should be presented.

One of the fundamental factors to consider in the successful manufacture of large forgings was that of not allowing the steel to become cold from the pouring of the ingot to the heat-treating operation. The cooling and reheating operations had, in Mr. Lynch's opinion, been the cause of many forging failures.

John L. Cox[2] wrote that many years ago, when forgings began to require ingots too large to be made from a single furnace, the first and most natural step was to combine two furnaces in one ladle and pour the ingot from that ladle. As the weight of the ingot grew still larger, this procedure became impracticable owing to the vast weight of the ladle containing several heats, and it became necessary to bring up separate ladles on several traveling cranes. These ladles could be poured into the mold at the same time or in succession, either through a common runner or through several runners. All of these methods had been tried at the plants doing large work, and if properly carried out, all would give satisfactory results.

Theoretically, and to a certain extent practically, there was an advantage in not mixing the metal in a common ladle nor pouring it through a common runner. If all the metal to go into an ingot were of a common composition, the variations in composition of the cast ingot would be affected by the uncontrolled action of the forces of liquation and segregation, with a resulting maximum difference of composition. On the other hand, if a heat of higher composition were poured in the bottom and metal of lower composition poured above it, the higher composition below would part with some of its components to the lower composition above, and an ingot of more uniform composition would result. Properly carried out, there would be no stop-pour and no fear of any defect at the plane of junction of the two heats. The whole interior of the ingot was fluid at the same time, and any lack of such common fluidity would be at once shown by a deep circumferential crack at the plane of junction, which would prevent the use of the ingot.

The matter of ghost lines was a comparative one. Practically all steel contained them. Their import and seriousness had been profoundly inquired into by the ordnance arms of the U. S. Government a number of times, as new generations of ordnance officers had arisen, because there was no place where defects could be more disastrous than in artillery, inasmuch as the factor of safety in ordnance was frequently not over $1^1/_2$—less than in any other type of engineering structure, in spite of the exceptionally severe service the steel was called upon to perform.

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[2] Assistant to President, Midvale Steel Co., Philadelphia, Pa.

The net result of all these investigations had been to show that unless of an exaggerated type, where, on turning, the chip would split upon crossing the ghost lines, the effect of the ghost lines was nil within the elastic limit of the material as used in construction, and was frequently without any influence whatever beyond it.

Inasmuch as they could not be altogether avoided in ingots of large size, it was reassuring to engineers to know that ghost lines of this type were in general entirely harmless.

A. P. Spooner[1] wrote that "large forgings" was a relative term; what one shop considered large another considered normal or small, depending on the type of work the shop handled. The steel producer had had to follow the demand of the engineer, and today, for certain high-grade work, his company used ingots weighing as much as 325,000 lb.

Control in steel production was the essential factor. Every increase in size and weight decreased directly the ability of the steel producer to exercise this control over chemical uniformity, internal and external strains, lines of segregation, effectiveness of heat treatment, and other possible irregularities. As examples: It was impossible to obtain as good physical properties in a 10-in. diameter bar, heat-treated, as in a 1-in. round bar, even though the bars were formed from adjacent sections of the mother ingot; also the chemical uniformity as shown by either analysis or lines of segregation could not be expected in a forging weighing, say, 100,000 lb. finished, requiring an ingot weighing 275,000 lb., as in a 10-lb. tool made from a small 300-lb. ingot, assuming that the producer in all cases exercised the utmost vigilance throughout. This was important and must be borne in mind by engineers when designing heavier parts and subjecting them to higher duty.

The biggest recent step forward in forging manufacture both to assure the consumer a satisfactory product and to assist the producer in developing his practice, had been, Mr. Spooner felt, the more general adoption of the original Bethlehem practice of hollow-forging, or of the boring and internal inspection of finished forgings.

Ghost lines, as usually referred to, could be divided into two types: those of considerable length and having depth in such form as to resemble a ribbon laid in the steel normal to its outer surface; and those which had little depth and which resembled strings laid in a longitudinal direction in the forging. The first or ribbon type must be looked on with suspicion and fully explored or eliminated, as under certain conditions in some compositions they developed into planes of weakness. The string type Mr. Spooner had never found to be detrimental.

Ghost lines as referred to by the author and shown by Fig. 2 in the paper, were present in all ingots and their number increased with the size of ingot necessary to produce the forging. The steel maker could control their location to a certain extent but could not eliminate them, because it was impossible to chill masses of molten steel instantaneously.

The behavior of string-type streaks under temperature changes had for years had a thorough practical test in all gun liners. Mr. Spooner personally knew of no gun failure due to irregularities of this type. Gun liners wore out by erosion caused by the high velocity of high-temperature gases. This wear was characterized by fire cracks running in every direction and therefore could not be attributed to possible streaks, which were always longitudinal.

N. L. Mochel[2] wrote that after visiting any of the steel plants in this country or abroad which were engaged in the manufacture of large forgings, one would find it difficult to agree with the author that large forgings had fallen into disrepute. Rather, one would be impressed by the ever-increasing use of larger and yet larger forgings, and by the fact that without the successful manufacture of large forgings, various engineering and industrial projects could not have reached their present high state of development.

The natural tendency toward the occurrence of any of the more common defects in steel forgings increased directly in proportion with the increase in size of the ingot necessary to produce the forging. It was therefore quite necessary in considering defects in forgings to bear in mind a general idea of the size of forgings being considered and the size ingot from which they were produced. The

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[2] Metallurgical Engineer, South Philadelphia Works, Westinghouse Elec. & Mfg. Co.

author did not in any way convey a definite idea as to the size of forgings he was discussing, the illustrations in general appearing to cover forgings which nowadays were considered rather small.

The Westinghouse Electric and Manufacturing Company during the past few years had used forgings weighing up to 80,000 lb. with diameters up to 63 in. and lengths up to 17 ft. overall, of which over one hundred have been produced in the last three years.

Normal pipe should cause no concern, as it was always necessary to crop sufficient from the top of all ingots to insure freedom from this natural condition. Secondary pipe and gas pockets, caused by the bridging or freezing over of molten metal in the cooling of the ingot, were defects of considerable importance which might exist in forgings. Much was known regarding their nature and occurrence, and methods have been devised for the careful examination of forgings to definitely determine that such defects were not present.

His company's experience in the matter led to the conclusion that ghost lines existed at some variable location in all large forgings. The lines were low in carbon, not necessarily high in phosphorus, but more often high in manganese and sulphur, and might or might not contain non-metallic inclusions. They did not feel that the composition was so radically different from the surrounding metal as to cause differences in expansion and contraction that would be of any consequence. As to the action under reversal of stresses, and the use of forgings exhibiting ghost lines, after careful examination of any forging, with their knowledge of the nature and occurrence of this condition, their experience with it and investigations on it, and of course considering the stresses to which the part would be subject, it was felt they were in a position to judge whether or not the usefulness of the forging was impaired.

The author failed to mention the often encountered and unsightly defects known as slag streaks, slag spots and sand splits. This type of defect appeared in that portion of the forging which was at the bottom of the ingot as cast, and was due to the non-metallic inclusions entrapped in a cone-shaped area at the bottom of the ingot due to the freezing of the metal from two directions, that was, from the sides and from the bottom plate. This condition probably existed to some extent in all ingots. Bottom crop was of course made in all cases, but the height of the cone of segregation appeared to be a variable matter, the nominal crop in some cases removing all of it, but in some cases not removing it all. This defect had been experienced to a considerable extent abroad as well.

Clinks, the author stated, were not necessarily produced by bad practice but were the result of not exercising proper care. The failure to exercise proper care, however, would appear to Mr. Mochel to be bad practice.

In all his company's large forgings a separate ingot was cast for each, and neither the ingot nor forging was allowed to become cold until after its first heat treatment, when it was ready for machining.

Clinks might occur in the ingot or forging in any heating or cooling operation, from the cooling of the ingot originally to the final cooling of the forging during the heat treatment. They might disclose fine- or coarse-grained metal, depending entirely on the state of the forging when the rupture occurred.

A. E. White,[1] discussing the paper orally, said that he thought all engineers would agree that although forgings might have their difficulties, where it was possible to produce forging, a forging was preferable to a casting.

One thing that might be mentioned in regard to the inspection of forgings was the possible use of the X-ray. At the present time, however, the X-ray could not be economically used to a thickness greater than two inches, and for forgings of 62 or 63 in. of solid metal this method of inspection was not, at least at the present time, applicable.

The author, in closing, said that the ghost lines shown in Fig. 2 of the paper were from a forging made from a 62-in.-diameter ingot weighing approximately 260,000 lb.

He wished to thank Mr. Spooner for drawing attention to the inability of securing the physical characteristics from a 100,000-lb. forging that could be secured from a 10-lb. one. However, he would not wish the designing engineers to believe that forgings did not possess better qualifications than steel castings of equal size. The matter of drilling forgings when hollow forging was not possible or practical was of great importance and it should be done in all cases. It had been demanded by his company's engineers for the past twenty years and had opened up many types of defects which might have gone along and caused failures, but which could be removed by proper boring or grinding.

He could not agree with Mr. Spooner in the matter of ghost lines being present in all forgings, for he had seen a great many large forgings without the slightest trace of ghost lines, and believed that the two classes of ghost lines to which he referred were only a matter of relativity as to size.

The danger from ghost lines was chiefly from reverse stresses, and he believed that Professor Moore of the University of Illinois, in his fatigue investigation, had shown the effect that notches have on fatigue strength.

As Mr. Spooner had stated, large guns failed by erosion of high-temperature gases at high velocities. However, their life was but a few cycles as compared to that of power-house equipment. The low number of heatings and coolings, although most severe, would extend over but a few days; turbine and boiler equipment, however, was expected to last for years.

It is for these reasons that, while he appreciated both Mr. Spooner's and Mr. Cox's remarks on ghost lines from the standpoint of a steel maker and a forge man, he could not agree with them from the point of view of modern power-house practice or equipment.

He wished to thank Mr. Cox for his remarks. He did not want in any way to intimate that a large mixing ladle or a common run was the only method of casting large ingots. It was an endeavor to show the danger from stop pouring or stop pours in the casting of large ingots, and the danger from large variations in the chemical composition between the ends of a large ingot poured from two heats.

He wanted to thank Mr. Lynch and Mr. Mochel of the Westinghouse Company for calling attention to the necessity of proper control and the proper inspection of large forgings.

[1] Professor of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich. Mem. A.S.M.E.

Engineering at the Science Museum

IN THE June 5 issue of *Engineering*, Edgar C. Smith reviews some of the interesting facts about the Science Museum at South Kensington, near London, England. The following paragraphs from his article are of interest generally to engineers:

For the purposes of administration the objects in the museum are divided into four main groups: (1) industrial engineering, including textile, agricultural, mining, metallurgical, and electrical machinery; (2) mechanical engineering, including stationary engines, road and rail transport, lifting appliances, pumps, measurement, and construction; (3) water and air transport, with sections devoted to sailing ships, steam ships, warships, boats, harbors, docks, lighthouses, and marine engines, airships, and airplanes; (4) science collections, with group of exhibits illustrating astronomy, mathematics, surveying, acoustics, optics, meteorology, geophysics and chemistry.

Generally speaking, any such institution as the Science Museum has three main functions to fulfill. It should be a storehouse for the historic apparatus and machines; it should be a great educational establishment aiming at enlightening the public in scientific matters, and it should also be the national industrial showroom where the technical man can make himself acquainted with modern progress.

But though wide be the range of exhibits to be found in the museum, wider still is the range of the interests of those who visit it. While the majority of visitors are without technical training there is day by day a steady stream of business men, professional engineers and craftsmen, teachers and students from all parts of the world who not only come to inspect the collections generally, but who expect to find something of value to them in their daily work. Specific inquiries relate to every branch of science and engineering. Oil mining, steam turbines, Diesel engines, calculating machines, kinematographs, rotary pumps, acoustical apparatus, water-tube boilers, wireless gear, motor-car engines, refrigerators, smoke abatement, uniflow engines, sanitary appliances, gravity escapements, magnetos, sounding machines, corrugated ships, and cotton gins are but a few things regarding which definite information has been asked for. A pioneer from the borders of Swaziland came recently to see how he could improve his water wheel; a group of sea-going engineers wanted to inspect such things as Doxford engines, flexible couplings, and nodal drives.

A collision on the Thames leading to a case in court led to an inquiry for gyroscopic compasses, while the objective of a power engineer was to inspect a coal-pulverizing plant. Instances such as these could be multiplied many times, and it is to meet the needs of such inquiries that it is essential that the museum should keep abreast of the times and that it should receive the support of the manufacturer.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Effect of Low and High Temperatures on Materials—Creep

THE effect of temperature on the properties of materials is said to be now recognized as being of the greatest importance to mechanical engineers. High-altitude flying of airplanes and airships and the low temperatures reached in refrigerating plants make it desirable to investigate the effect of low temperature on metals, and the increased tendency to use higher degrees of superheat in connection with steam and higher temperatures in internal-combustion engines, as also the desire to use vessels under high temperatures and pressures for the "low"-temperature carbonization of coal, make a complete investigation of the change in properties of metals with temperature a matter of great importance. The present paper is based on tests described in detail in the original. The low-temperature tests were carried out on steels, in particular those containing 0.14 and 0.32 per cent carbon. In these two types of steel the minimum strength occurs at about the freezing point of water. The changes in tensile properties, however, as between 15 deg. cent. and —65 deg. cent. are not very great; impact tests show a greater change.

A series of tests on elastic and other properties of certain steels were carried out for the range of temperatures from 15 to 500 deg. cent. The conclusion to which the author arrives from these tests is that it is desirable to know the exact conditions of the steels before comparing them with tests at definite temperatures, and the properties of steels even at ordinary temperature depend upon their previous history. The original paper gives a table showing the strength of quenched and tempered steels when tempered at various temperatures, and the results of tests of reeled bars at various temperatures.

Taking, for example, the 0.65 carbon steel, it is found that a considerable change takes place in the limit of proportionality between 200 and 300 deg. cent. but the limit of proportionality given by the curves in the original paper is not by any means a fixed limit, as it can be raised artificially by "overstressing" in tension. The elastic range can be raised to a very marked extent by repeated stresses, and many million repetitions are possible for ranges of stress higher than twice the stress at the apparent limit of proportionality as determined by the tension test. The limits of proportionality as determined by static tests at temperatures above 300 deg. cent. have not much significance as far as fatigue ranges under alternating stresses are concerned, and they only indicate, therefore, the stress above which a certain permanent strain is produced.

In an earlier communication the author has shown that for low-carbon steels, thoroughly normalized, the maximum strength occurs at between 200 and 300 deg. cent., according to the carbon content, and has also shown that for "Armco" iron the strength at about 230 deg. cent. is 40 per cent greater than at ordinary temperatures. Taking the lowest value of the ultimate strength of the normalized 0.32 carbon steel at ordinary temperatures and comparing it with the maximum obtained on the reeled bar, the maximum increase of strength of this steel as the temperature of test increases is 20 per cent of the strength of the normalized steel at ordinary temperatures. Whereas, comparing it with the strength of reeled bar at ordinary temperatures, the increase is only 12 per cent. As previously pointed out by the author, the properties of these steels at ordinary temperatures depend, therefore, upon the previous history. Comparing these results with the creep tests which are to be described later, it will be found that at 350 deg. cent. creep took place for more than three days at 22.5 tons per sq. in., but finally ceased, and that at various stresses up to 34 tons per sq. in. the creep was continuous and the bar broke. Up to about 350 deg. cent. the strength of this steel normalized is really very nearly constant.

Creep

The author puts forward a hypothesis dealing with creep which the experiments described in his paper are claimed to confirm. This hypothesis is as follows: At each temperature there is a particular stress below which the metal may be temporarily viscous, i.e., it continues to deform under a continuously applied stress, but with time the viscous material solidifies and the rate of creep diminishes to zero. Above this stress the material continues viscous and with time will finally fracture.

A series of tests dealing with the phenomenon of creep are described in the original paper. From these it would appear that what is generally called a breaking stress at ordinary temperatures is

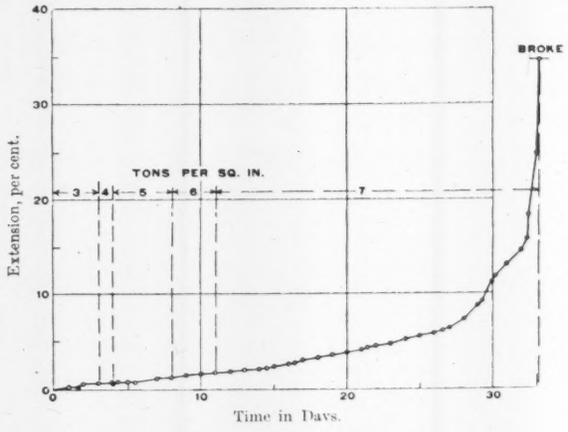

FIG. 1 ALLOY STEEL TESTED AT 525 DEG. CENT.

(Composition: C, = 0.35 per cent; Cr, 35 per cent; Ni, 1.25 per cent. Ultimate stress at 15 deg. cent. (ordinary test), 55 tons per sq. in.; at 525 deg. cent., 25 tons per sq. in.)

approximately the load divided by the original area which will cause continuous creep; this stress can be approached very nearly without continuous creep taking place.

At the present time the author has a specimen in a testing machine which has been loaded continuously and at gradually increasing stress for several months. This is now carrying a load greater than that which would have broken the specimen. Other tests show that the time effect is all-important.

The results obtained in these tests and tests at constant stress and varying temperatures indicated the serious difficulty of finding the real ultimate breaking stress of a piece of metal. The technique about to be described was therefore developed in the hope of throwing light upon this problem. From Fig. 1 it will be seen that at certain stresses the creep gradually became zero, while at other stresses it did not become zero. This suggests a slow, but, compared with Fig. 1, a fairly rapid method of determining the stress for any temperature below which, with time, the viscous material solidifies, but above which the viscosity continues until fracture. Consider Figs. 2 to 4, which are drawn from tests of steel containing 0.32 per cent of carbon, and in which the vertical ordinates are elongations and the abscissas time. It will be noticed that at certain stresses the elongation-time curves at constant stress become parallel to the axis of time; in others, not. The rate of creep which appears for several hours to be constant, can now be measured by the slope of the lines AB of Fig. 2. If then, from these curves, stress-rate of creep curves are plotted, as in Fig. 5, these curves cut, or become tangent to the axis of stress at some particular stress. This is at least very approximately the stress below which the material will solidify with time, under stress, but above which it

continually creeps. The stresses at which the rate-of-creep curve touches the axis of stress may be called the "*w*" stress (f_w) or temperature-viscosity stress.

The importance of the results obtained by the author in connection with vessels under pressure at high temperatures is apparent. A mild steel at 400 deg. cent. will be perfectly safe up to 14 tons per sq. in., but if the temperature is maintained at 500 deg. cent. the failing stress with time is less than 4 tons per sq. in. At 6 tons per sq. in. it would take very many days before the creep was sufficient to cause serious trouble. The importance of preventing the temperature rising 25 per cent is much greater than the stress rising by the same percentage.

An alternative method of determining the temperature-viscosity stress was also developed by the author. In this, the rate of creep is interpolated fairly accurately by loading very gradually and noting with a sufficiently sensitive apparatus the elongation of the specimen. Then by taking readings sufficiently often the actual creep in certain intervals of time can be obtained and the rate of creep per hour at certain stresses ascertained. Whereupon curves such as those shown in Fig. 5 can be plotted. The results of static tests carried out indicate that at comparatively low stresses and at temperatures above 450 deg. cent. the material will deform continuously when the stress is applied in one direction. They also show that above 450 deg. cent. the limit of proportionality may be very low, indeed. If, however, as referred to above, the material is subjected to rapid fluctuations in stress, first in tension and then in compression, mild steel and alloy steels are capable of resisting

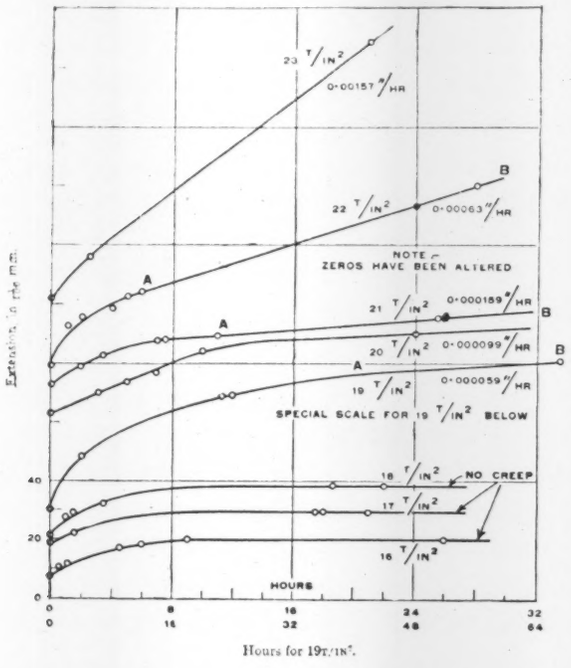

FIG. 2 0.32 PER CENT CARBON STEEL. 400 DEG. CENT. (EXTENSION-TIME RELATION)

very high ranges of stress for very many millions of repetitions without fracture. The author names extensive tests indicating the correctness of the above statement and uses them to show the remarkable effect of time upon the properties of these materials. Repetition stresses are being made at the rate of 2000 cycles per minute, and there is therefore no time, especially when the stress is reversed, for the creep phenomena to operate in any marked degree.

HARDNESS OF METALS AT HIGH TEMPERATURES

Both static and dynamic tests were carried out. From these it would appear that up to a temperature of 500 deg. cent. the hardness curves, whether obtained statically or dynamically, give indications of the tensile strengths as obtained in the ordinary way, but they do not give indications of the temperature-viscosity stresses. Neither do they give any indication of the form of the curve for repetition ranges of equal plus or minus values.

One of the important conclusions to which the author arrives is that the control of temperature when materials are subjected to temperatures of more than, say, 350 deg. cent. is more important than the control of pressure. For high-pressure boilers and superheaters of mild steel the factor of safety for temperatures of 800 deg. fahr. (427 deg. cent.) for a continuously applied stress of 6 tons per sq. in. is only about two, but this is claimed to be ample provided the temperature is not exceeded.

The results of the tests on materials at high temperatures sub-

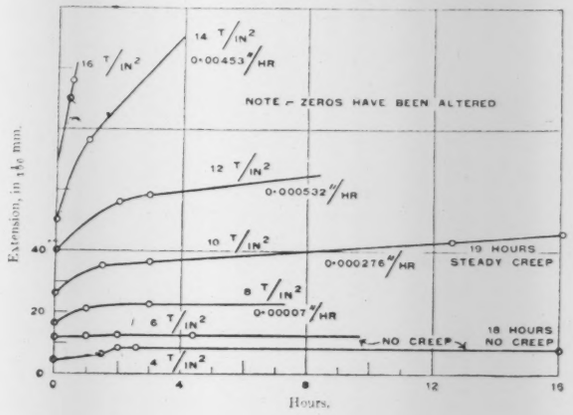

FIG. 3 0.32 PER CENT CARBON STEEL. 500 DEG. CENT. (EXTENSION-TIME RELATION)

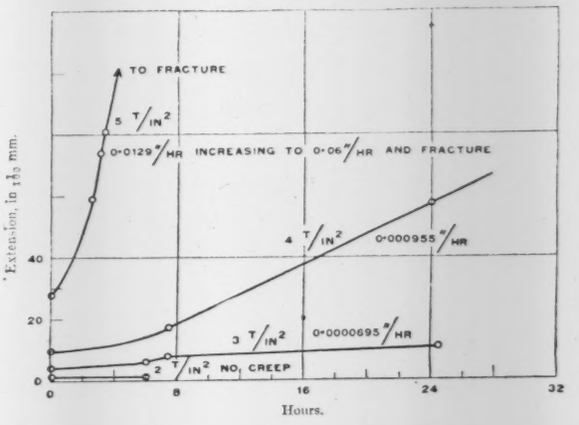

FIG. 4 0.32 PER CENT CARBON STEEL. 600 DEG. CENT. (EXTENSION-TIME RELATION)

jected to repetition stresses show that very many millions of rapidly repeated stresses of magnitudes far greater than the creep stress can be applied without risk of fracture. These results throw important light on the possibility of materials healing after slipping, and indicate that visocity plays an important part in the behavior of materials subject to rapid repetitions of stress at high temperatures. If the fluctuations of stress are small and the stress is always in one direction the conditions approximate more and more the static condition; and further, if the time of application in one direction is not very small, the time factor becomes of great importance, and failure may occur. The full significance of the repeated stresses is left, however, for a future communication.

In the discussion of this paper in London on Dec. 5, 1924, H. J. Tapsell, of the National Physical Laboratory, gave some literary references on previous work dealing with the phenomenon of creep. Its importance was confirmed by work done at the National Physical Laboratory when, e.g., valve steels were tested to very high temperatures and it was found that the rate of loading was a very important factor. Information about these and similar tests was published in the Annual Report of the National Physical Laboratory for 1923. These tests lasted a much longer period than those of Professor Lea, and showed, for instance, that the creep did not become constant necessarily within a few hours or days. The creep tended to approach a constant rate only after perhaps several weeks. For example, in one of the Mr. Tapsell's tests in which the failure occurred in 79 days, the creep did not attain an approximate steady

rate until 30 days after the commencement of the test. In another test of a test piece which was loaded for 142 days the creep had not even then attained a constant rate, although the elongation had reached 11 per cent on the test piece.

In the curves which Mr. Tapsell had obtained on the tests lasting for several weeks, the first part of the curve, representing the first few days, was decidedly curved in its character, but if he took his reading for those first few days and plotted them to a much more open scale, he got an apparent straight line toward the end of the period. The straight line, however, was really fictitous; it was not a straight line at all. If the tests were continued long enough and the points were plotted, it would be found that the curve went on for a long time, the rate of creep per day being exceedingly small, of course, and decreasing. The curve, Fig. 6, tended to become straight in

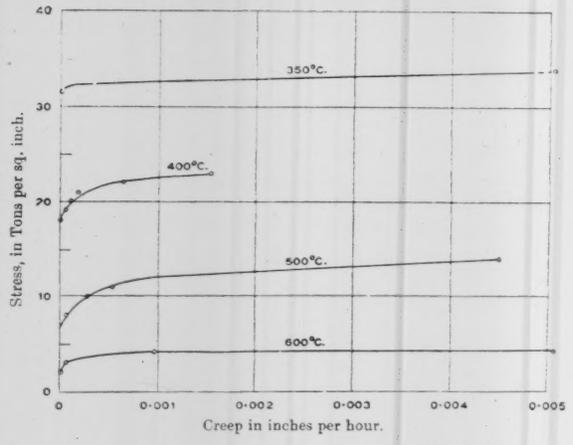

Fig. 5 0.32 Per Cent Carbon Steel. Stress-Creep Relation

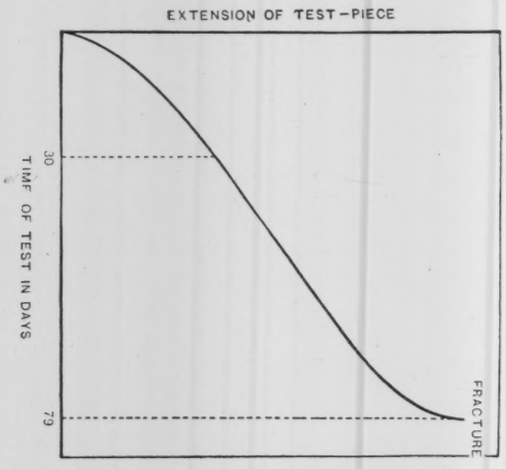

Fig. 6 Typical Curve of Extension against Time

this particular case only after about thirty days, so that the slope of the approximate steady rate was much different from the slope attained after a few days' test. If Professor Lea was intending to take the slope of the curve where creep became more or less steady or constant, he should go beyond the first few days of the test. The procedure at the National Physical Laboratory had been to explore thoroughly the behavior of creep over these long-extended intervals in the case of one or two materials, not to make short-time tests on a number of materials.

From tests which had been made at the Laboratory it had been possible to estimate the load which, put on the test piece, would not cause fracture, although allowed to remain on for a considerable length of time. This load divided by the original cross-section they called the limiting creep stress of the material. The values obtained showed that the limiting-creep-stress curve, i.e., the maximum stress that could be applied without causing ultimate failure in a very long time, seemed to come in as shown in Mr. Tapsell's diagram, and he indicated also how it ran into the ultimate-stress curve at a point below the maximum value. The position of the maximum value of ultimate stress, of course, depended to some extent on the rate at which the test was made.

In the discussion of the same paper in Manchester, Dec. 18, 1924, R. W. Bailey, referring to the method employed by Professor Lea to determine the creep stress as illustrated by Fig. 5, stated that it would be noted that the curves bent down rather sharply in the vicinity of and at the axis of zero creep, and it would appear to be extremely difficult to predict by the method employed the stress up to which continuous creep would not occur. If, instead of plotting the stress against the rate of creep, the logarithm of the rate of creep was used as the abscissa, a different limiting stress might be obtained, or a stress for which the rate of creep was so small that for practical purposes it might be regarded as nil. Dickenson's evidence certainly indicated that for the temperatures he employed there was a continuous creep, and no indication that it ceased at rates which were lower than those recorded by the author.

There appeared to be a very good reason for thinking that at elevated temperatures, if there were any permanent extension, then creep would proceed without cessation; namely, that at temperatures at which strain hardening was removed by thermal treatment the very factor which was responsible for the arrest of extension at lower temperatures was absent. The process of wire drawing was of interest in this connection, where commonly a low-temperature treatment at about 550 deg. cent. was applied to remove the effect of drawing prior to further reduction. It would appear that the author's hypothesis regarding the limiting creep stress was based largely upon tests made at 350 deg. cent. Very considerable changes in steels took place at temperatures above 350 deg. cent. The results obtained by Dickenson must be regarded as reliable, and these and the reason just given caused doubt whether the author's hypothesis was applicable at temperatures much above 400 deg. cent. It was clear that the most satisfactory progress and results could only be obtained by a close coöperation of the metallurgist and the engineer. It was of interest to refer to the special steels and alloys now being developed to have high tensile properties at elevated temperatures and to note that the trend was in the direction of alloys of the solid-solution type and high melting point, which as a rule were more free from thermal changes than the ordinary steels. (Paper by Prof. F. C. Lea of the University of Sheffield, in *Proceedings of the Institution of Mechanical Engineers*, no. 6, 1924. Original paper pp. 1053–1096, discussion pp. 1115–1168, 60 figs., *et A*. Part of the discussion is devoted to paper entitled, The Elastic Limit in Tension and Influence on the Breakdown by Fatigue, by J. M. Lessells, which may be abstracted in a future issue if space is available.)

Short Abstracts of the Month

AERONAUTICS (See also Internal-Combustion Engineering: Design of Air-Cooled Cylinders; National Defense; The Fleet and Aviation)

The Round Germany Flight

This flight took place in the early part of June with 91 machines entered. Five separate circuits were laid out with an average length of approximately 670 miles, all of Germany being criss-crossed in such a manner that there would be few towns of any size which would not be visited by the competing machines. The competition was a reliability trial above all, the aim being neither speed nor carrying capacity but simple mileage.

Flight, a British publication, in an editorial points out that it gives one food for thought that a vanquished country like Germany should be able to get together more than 90 machines for such a competition, and thinks that this flight marks the beginning of Germany's effort in the air.

Practically all of the larger companies took part in the competition. The following information is given as to some of the machines least known in this country.

The Baumer Aero Co. has put out two machines, B-II and B-III. The former is a monoplane two-seater designed for rapid dismantling and erecting, each wing, rudder, elevator, etc., being

removable by unfastening two bolts. The B-III is a biplane with a landing speed claimed to be as low as 37½ m.p.h. Both are fitted with Wright L-4 engines rated at 60 hp.

The Daimler Co. entered two machines, one of which (L-21) is fitted with two Mercedes engines each rated at 19 hp., so that in spite of being twin engined the machines may be fairly described as light planes. The other machine (L-20) has been so arranged as to be suitable for use both as a light plane and a glider. When it is desired to use it as a glider the wings are swept back at a considerable angle so as to bring back the center of pressure. The engine is removed and a nose cap fitted over the front of the fuselege. With this arrangement the absence of the engine in front is balanced by the backward sweep of the wings and the machine retains its trim fore and aft. (*Flight*, vol. 17, no. 22, 857, May 28, 1925, pp. 317–326, illustrated, and editorial on p. 316, *d*)

Fuel-Consumption Competition in France

THE Solex Carburetor Co. offered a prize of 50,000 francs for the first French pilot who would fly before Jan. 1, 1925, from Paris to Rouen (91.2 km. = 56.7 miles) with a consumption of not more than 1 kg. (2.2 lb.) of gasoline and oil, and provided further, that if no one succeeded in doing so, the prize should be awarded to the pilot who would make the same flight before the first of April, 1925, with a minimum consumption not to exceed 3 kg. (6.6 lb.).

On Mar. 26, Maurice Drouhin in a Farman "Mostique" monoplane, equipped with a Salmson 16-hp. three-cylinder V-type motor, flew under rather unfavorable weather conditions from Paris to Rouen with a consumption of 100.8 grams (0.22 lb.) of oil and 2.817 kg. (5.18 lb.) of gasoline. (*L'Aéronautique*, vol. 7, no. 72, May, 1925, p. 172, *g*)

General Patrick's Recommendation Concerning the Air Service

AN OFFICIAL letter addressed to the Adjutant General, War Department, on the subject of reorganization of air forces for national defense, dated Dec. 19, 1924, and written by Maj-Gen. Mason M. Patrick, Chief of Air Service, U. S. Army.

Only the main conclusions are reported here. The writer is convinced that the ultimate solution of the air-defense problem of this country is a united air force. Until the time when such a radical reorganization can be effected certain preliminary steps may well be taken. Among these, additional functions should be placed upon the Chief of Air Service, putting the latter in a relation to the War Department somewhat similar to that occupied by the Marine Corps in the Navy.

An unsatisfactory condition exists in the Air Service as it is, and in order for it to develop and assume its proper place in national defense, a departure from present methods must be inaugurated. The promotion situation in reference to the commissioned personnel is considered unsatisfactory, and special regulations must be provided for the Air Service. The training of the non-flying part of the enlisted personnel for the Air Service should be also changed.

"The great mobility of the Air Service and the missions it is capable of performing have created a problem in command, the solution of which is still far from satisfactory. It is comparatively easy to place limitations—actual boundaries on the ground—between a theater of operations, a zone of communications, and a zone of the interior; but for the Air Service these all merge into one. Command becomes complicated, and somewhat overlapping, when air forces based on airdromes in the zone of the interior carry our missions into the theater of operations in connection with the ground troops or far beyond the hostile lines. The Lassiter Board has chosen to state that 'this force should be organized into large units, insuring great mobility and independence of action.' Future emergencies will require at the very outset, before the ground armies can get under way, and in many cases before the Navy can make its power effective, the maximum use of air power on strategic missions. Provision for the command of these air forces has not been satisfactorily made, nor it is known by me that there are even provisions for such initial air operations. We should gather our air forces together under one air commander and strike at the strategic points of our enemy—cripple him even before the ground forces can come into contact. Air power is coördinate with land and sea power, and the air commanders should sit in councils of war on an equal footing with the commanders of the land and sea forces.

". . . .The Army Air Service should be definitely charged with all air operations conducted from shore stations. . . .There should be in war plans one air commander, who, in at least the initial stages of an emergency, should control all operations of the air forces, both in the performance of distance strategic missions and in joint action with the land and sea forces." (*Aviation*, vol. 18, no. 24, June 15, 1925, pp. 662–663, *g*)

CORROSION

The Study of Corrosion

THE Progress Report of its Corrosion Committee was presented to the American Institute of Chemical Engineers on Feb. 3, 1925, and accepted by the Council. From this report it would appear that there are a number of corrosion committees now at work.

The Corrosion Committee of the National Research Council is a sort of "steering committee" on corrosion and endeavors to coördinate and systematize all coöperative effort in this country in the field of corrosion research. It undertakes no research work of its own and does not have any special corrosion field. The following committees are coöperating with the Corrosion Committee of the National Research Council, and their scope is as follows:

American Society for Testing Materials. Committee A-5 is working on the corrosion of iron and steel, with particular reference to outdoor tests on atmospheric corrosion. In addition it is instituting a further program.

Committee B-3 is interested in accelerated corrosion tests, with particular reference to non-ferrous metals and alloys, and has several committees coöperating with the Bureau of Standards and Bureau of Mines.

American Chemical Society and American Electrochemical Society. These organizations have committees interested in theories and mechanisms of corrosion as distinct from its practical aspects.

American Institute of Chemical Engineers. This society takes up specific problems affecting chemical-engineering work and has a wide field in its investigation of chemical corrosion. It is interested in the selection of materials for the construction of corrosion-resisting chemical apparatus.

American Society of Refrigerating Engineers and American Foundrymen's Association. These organizations are interested in specific problems relating to their industries, and not so much in direct work on the theory of corrosion. In connection with the building-code committee, the A.F.A. is making studies in pipe-corrosion conditions, the work being directed by Professor Whipple of Harvard. Gas attack of interior pipes and diffusion of gases is also being covered by the A.F.A. committee. Another question this committee discussed at one time was the advantages of determining the influence of internal structure of metal on the rate of corrosion. It has in mind to gather information, but not to do any real research.

American Committee on Electrolysis. This body is doing active field work with the Bureau of Standards on corrosion of various pipes for various types of soils.

In addition to the foregoing, the Bureau of Standards is working on corrosion under the direction of Burton McCollum, collaborating with the American Electrolysis Committee and the Bureau of Mines though not coöperating directly with the Council, which is working on corrosion problems of its own. (*American Institute of Chemical Engineers*, Bulletin No. 30, Proceedings of the 17th Annual Meeting, Dec. 3–6, 1924, pp. 45–50, *g*)

ENGINEERING MATERIALS

New Bronzes

AMONG the compositions recently placed on the market the following may be mentioned.

Steel bronze is an alloy containing 52 per cent copper, 43 per cent zinc, 3 per cent manganese, 1 per cent iron, and 1 per cent aluminum. The alloy as cast has a tensile strength of 50 kg. per sq. mm. (71,100 lb. per sq. in.), an elastic limit of 20 kg. per sq. mm. (28,440 lb. per sq. in.) with 20 per cent elongation, and therefore its physical properties approach those of mild steel, remaining superior to it, however, from the point of view of corrosion. The tensile strength

and elastic limit of this material are materially improved by hot forging, pressing, rolling, etc., while the elongation remains as before. The tensile strength and elastic limit can be increased, respectively, to 70 kg. per sq. mm. (99,540 lb. per sq. in.) and 32 kg. per sq. mm. (45,400 lb. per sq. in.) and the elongation raised to 23 per cent by increasing the joint content of iron and aluminum to 3 per cent. It is stated that the material is very resistant to corrosion and is not affected by sea water or dilute acids. It is somewhat more difficult to forge than other bronzes. Extremely pure zinc must be used in the manufacture of this alloy, as lead has an extremely strong tendency toward segregation, which affects the strength of the material very undesirably. This tendency is still greater if tin is present, particularly in contents in excess of 0.8 per cent. If such is the case, a lead-zinc eutectic alloy is formed with a very low melting point and this produces a substantial weakening of the strength of the material.

Manganese bronze, a somewhat similar type, has a content of 55 to 60 per cent copper, 39 to 45 per cent zinc, about 2 per cent iron, 0.5 per cent manganese, and 0.5 per cent aluminum. This material forges well at a temperature of about 800 deg. cent. (1472 deg. fahr.), and is quite similar to Delta metal and Durana metal. (*Das Metall*, supplement to *Zeitschrift für die Gesamte Giessereipraxis*, vol. 46, no. 22, May 31, 1925, pp. 93–94, *d*)

FUELS AND FIRING (See Internal-Combustion Engineering: Centrifugal Treatment of Diesel Fuel Oils)

INTERNAL-COMBUSTION ENGINEERING (See also Aeronautics: Fuel-Consumption Competition in France)

A Proposed Solution of the Double-Acting Diesel Engine Problem

THE proposed engine is a true double-acting engine having a piston of normal length and two sets of ports which alternate between scavenging and exhaust.

The shifting of these ports between scavenging and exhaust is controlled by rotary valves which perform no other function and

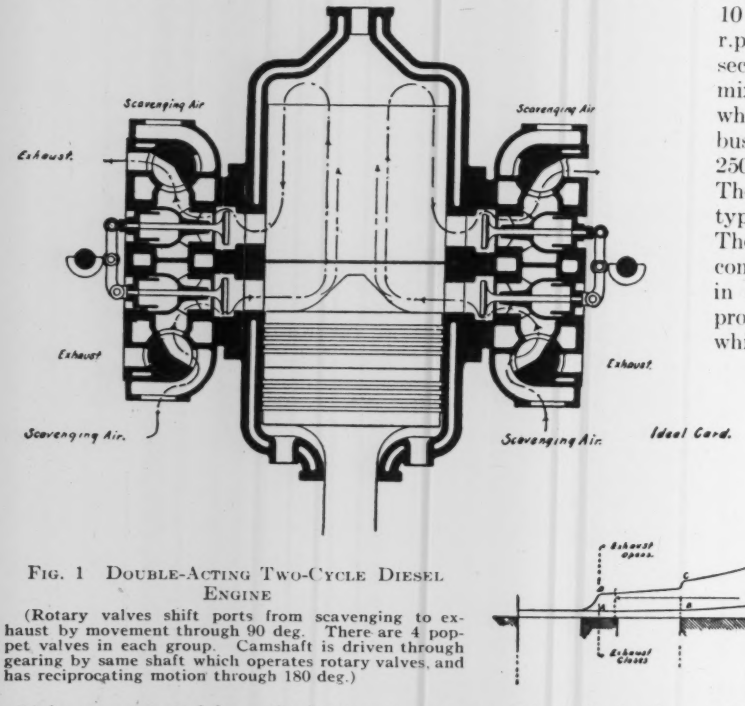

FIG. 1 DOUBLE-ACTING TWO-CYCLE DIESEL ENGINE

(Rotary valves shift ports from scavenging to exhaust by movement through 90 deg. There are 4 poppet valves in each group. Camshaft is driven through gearing by same shaft which operates rotary valves, and has reciprocating motion through 180 deg.)

which are protected from the heat and pressure of the cylinder by four sets of poppet valves placed between them and the cylinder ports.

These rotary valves are therefore subject only to the scavenging pressure and to a temperature which, being a mean between the exhaust and the scavenging temperatures, is not higher than that in the valve chests of high-pressure steam engines.

The working cycle of this engine is shown on the ideal card. At the point *A* the exhaust is closed and compression into the combined clearance space takes place.

This action is due to the closing of the cam-operated poppet valves, and the result is that, at the point *B* where the port is closed by the piston, there is a materially higher pressure in the cylinder than would be the case if no poppet valves were fitted. The effect of this action is to give a materially greater effective stroke with a given length of port.

From the point *B* compression and expansion are normal to the point *C*, where the exhaust is uncovered by the piston. At this point there will be a drop in pressure, by expansion into the port clearance space, but the useful-work card will be continued to the point *D*, where the cylinder is opened to exhaust by the lifting of the poppet valves. (Capt. A. M. Proctor, U. S. N., in *Journal of the American Society of Naval Engineers*, vol. 37, no. 2, May, 1925, pp. 309–311, *d*)

The Internal-Combustion Turbine

Two papers on this subject were recently published in England. One was presented before the Institution of Engineers and Shipbuilders in Scotland by Prof. W. J. Goudie, and the second, entitled The Gas Turbine, was presented before the North-East Coast Institution of Engineers and Shipbuilders by M. König.

It is apparent from the descriptions given in these papers that a considerable amount of progress has been made in the direction of producing large and efficient internal-combustion turbines. The greatest credit must be given to Holzwarth, who in spite of very great difficulties has gradually improved his designs, both as regards size and efficiency, until now, based upon the results obtained with previous machines, he is stated to have just completed a turbine of 5000 kw. capacity, the machine being ready for testing, while the designs for a 10,000-kw. unit have been prepared. On his previous units he has obtained an overall efficiency of 14.2 per cent with an oil turbine of 300 kw. capacity, and 14.6 per cent with a gas turbine of 700 kw. capacity, these figures being measured on the basis of fuel to kilowatts. It is of interest to note that the 5000-kw. turbine consists of a single Curtis wheel, 10 ft. in diameter, weighing 12 tons, and having a speed of 1000 r.p.m. The nozzle height is about 4 in., and the length of the second ring of moving blades is approximately 6 in. The working mixture is compressed to a pressure of about 50 lb. per sq. in., whence it passes at a temperature of 200 deg. fahr. to eight combustion chambers, where it is ignited, the pressure rising to about 250 lb. per sq. in., and the temperature to almost 3000 deg. fahr. The burnt gases then expand through nozzles of the built-up type to slightly above atmospheric pressure in the wheel chamber. The blades are made of a soft electrolytic iron of very low carbon content, the blade, shrouding, and packing piece being stamped in one piece. It has been demonstrated that this material has proved itself superior to alloy steel or any other harder material, which have been found to be unsuitable owing to alteration of their molecular structure and disintegration at the surface. After expansion of the burnt gases is finished (the time occupied is about 0.2 sec.), air at slightly above atmospheric pressure is scavenged through the combustion chamber, the nozzle valve, the nozzle and the wheel chamber for a period of about 0.8 sec., after which the nozzle valve closes and a fresh charge of air and gas is admitted, the time of charging being 0.5 sec., while the average temperature in the wheel chamber is, owing to the effect of scavenging, only about 800 deg. fahr. As already noted, this latest machine of Holzwarth has not yet been subjected to extensive trials, but it is certain that considerable confidence must be felt in the possi-

bilities of the design to justify the expense of constructing so large a unit. The results of the test of this machine will certainly be awaited with interest. (Editorial in *The Power Engineer*, vol. 20, no. 231, June, 1925, p. 202, *g*)

MACHINE DESIGN

Rotary Machinery Capable of Running at Very High Speeds

DESCRIPTION of a new type of small turbine capable of running at very great rates of speed, so arranged that the rotor is free of all contact, solid or liquid, with the stator, and capable of selecting its own axis of rotation.

The principle of the machine is shown in Fig. 2. The machine consists of a stator *A* provided with a conical hollow spacing having a vertical axis. Into this spacing open a number of tuyeres *t*, the axes of which are located as equidistant generating lines of a single-sheeted hyperboloid. When supplied with compressed air these tuyeres provide a series of divergent jets producing a gaseous envelope which rises with considerable turbulence. The rotor in its lower part has the shape of a cone or one similar thereto, and is acted upon in the region of approach by jets of gas directed nearly along meridional lines.

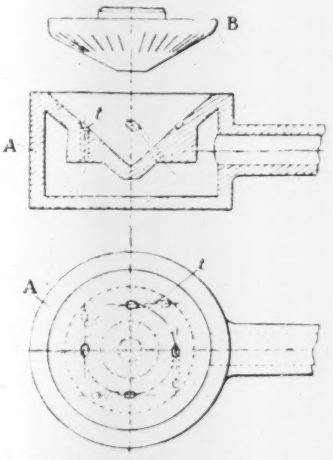

FIG. 2 SUPER HIGH-SPEED TURBINE

The rotor, located at a convenient distance from the stator, is drawn toward the latter by the turbulent action, but when it comes nearly in contact therewith it is repelled by the layer of compressed gas. Left to itself it finds a position of equilibrium and begins to rotate rapidly, and being thus both supported and moved by the gaseous cyclone flow, it can acquire very great velocities, always being held away from the stator at certain points at a distance of only a fraction of a millimeter. A slight inequality in the distribution of the flow from the tuyeres produces usually a precessional movement, in the course of which the axis describes a very sharp cone at the rate of one revolution in from one-half to one hour. Any sudden disturbance of the rotor will give it a movement of nutation of a certain frequency depending upon its moments of inertia about the axis of revolution and the principal transverse axis.

The authors state that based on this principle they have built three types of turbines moved by compressed air or compressed anhydrous carbon dioxide. In the first model the rotor has a diameter of 45 mm. (1.77 in.) and runs at a velocity of 1300 r.p.s. or at a peripheral velocity of 185 m. (607 ft.) per sec. A copper ring placed on the turbine flies apart. A third model with a diameter of 11.7 mm. (0.47 in.) attained a measurable speed as high as 4000 r.p.s., but there is reason to believe that the actual maximum speed was in excess of 11,000 r.p.s., equivalent to 660,000 r.p.m. The authors are at present engaged in the construction of rotors of special steels which it is expected will be capable of withstanding a velocity of 1,000,000 r.p.m. (E. Henriot and E. Huguenard in *Le Génie Civil*, vol. 86, no. 22, May 30, 1925, pp. 538–539, 2 figs., *dA*)

MACHINE TOOLS

The Butler Shaft-End-Squaring Machine

TO FORM squares or hexagons on the ends of shafts the usual procedure is to straddle-mill two opposite faces at a time, using a special fixture where the quantity is sufficient to warrant the expense, or using a dividing head and chuck for single parts or small quantities. The following is a description of a machine constructed by the Butler Machine Tool Co., Halifax, especially for forming by straddle-milling squares or hexagons on the ends of shafts or screws.

In operation the work is straddle-milled by two inserted-blade milling cutters, the work being indexed after each pair of flats are milled to obtain the square or hexagonal form required.

The two cutters are carried by two spindle headstocks adjustable toward each other along the short bed of the machine, the adjustment being effected by the operation of a crank handle at the end of the bed. The spindles are interconnected by the shaft at the rear of the machine, both being driven by one pulley.

The shaft to be milled is gripped in a collet chuck for which twelve sets of collets are provided, the sizes ordinarily being $^3/_8$ to $1^1/_2$ (rising by eighths), $1^3/_4$ and 2 in. diameter, 2 in. being the largest size admitted through the chuck. This collet chuck is arranged for easy rotation by hand and is fitted with a dividing plate giving two, three, four, and six divisions. The entire collet chuck and dividing and rotating motion is carried in a subsidiary slide on the main slide; the subsidiary slide enabling the work to be adjusted vertically between the cutters while the main slide is used to feed the work horizontally between the cutters. With this arrangement the work is first fed horizontally between the cutters until the correct length is milled, when the radius left by the cutters at the finish of the cut may be removed, if required, by using the vertical traverse of the subsidiary slide. (*British Machine Tool Engineering*, vol. 3, no. 33, May-June, 1925, pp. 258–259, *d*)

METALLURGY

Dilatometric Investigation of Cast Irons

THE authors claim that this method of investigation—carried on by means of a registering differential dilatometer invented by Pierre Chevenard—gives a convenient and precise method for analyzing the graphitization of cementite, a matter which may acquire considerable importance. This is based on the fact that not only is the formation of graphite in the solid state accompanied by a considerable expansion, but the observation of the Curie specific anomaly of the cementite, both in heating and in cooling, permits evaluating approximately the quantity of carbon in combination at the beginning and at the end of the thermal cycle. This enables one to gain an insight into the variations of the state of the carbon in the course of the cycle by measuring the expansion alone. The authors apply their method to the study of the influence of silicon on the graphitization of irons, the formation of complex cementites, including such carbides as manganese and chromium, and the temperature of transformation in stable and unstable systems. They expect by this method to be ultimately in a position to present the tendency to graphitization of cast irons in the same way as the ability of a steel to take an anneal is known today. (Pierre Chevenard and Albert Portevin in *Comptes Rendus des Séances de l'Académie des Sciences*, vol. 180, no. 20, May 18, 1925, pp. 1492–1495, 2 figs., *e*)

A paper on the same subject, under the title Dilatometric Study of Graphitization, is to be presented by the same authors as an annual exchange paper of the Association Technique de Fondéries de France before the convention of the American Foundrymen's Association to be held Oct. 5–9, 1925, in Syracuse, N. Y.

Heat Treatment of Cast Iron

THE author attempts to show that the physical properties of cast iron can be materially modified by suitable heat treatment, and that the addition of alloying elements as well as close chemical control of the cupola will give results that are desirable.

The annealing operation which the author recommends is as follows: The parts are heated to 1750 deg. fahr. for a short time. Then the machining operations are performed and the parts returned to the heat-treatment department for quenching and drawing. This gives a material having a hardness practically equivalent to the original chill but without any tool trouble and loss of material.

It is very important that the complete breakdown of the cementite be accomplished, otherwise quenching cracks will generally result. It has been definitely proven that this reaction is a case of time, temperature, and mass. For example, if the heat is applied long enough at 1300 deg. fahr. (705 deg. cent.), the same complete graphitization is accomplished that is effected by heating to 1750 or 1800 deg. fahr. (955–985 deg. cent.). The time, however, in the latter case is greatly reduced.

It might be mentioned that an exhaustive test was run to determine the best material for certain valve tappets. Among the materials tested were properly heat-treated steels (S.A.E. 1020, 2320, 3250, and 6150) and chilled iron. The steels in each case showed a checked or roughened surface after 8 hr. of running, while the chilled iron retained a perfectly smooth mirror surface. In order to increase the life of the wearing end which was in contact with the push rod, a cyaniding operation or a simple oil quench was made use of. This gave the required hardness.

As regards alloying elements for cast iron, it is stated that at present the standard mix contains small amounts of chromium and nickel. Chromium helps the chilling quality of an iron, while nickel seems to retard it. Nickel increases the general hardness and strength. Copper has much the same effect in amounts up to 1 per cent. Nickel gives the best results of all of the alloys tried as it increases the bending strength materially and the tensile strength about 15 per cent.

The author claims also that a white iron can be broken down very quickly; by heating to 1800 deg. fahr. (984 deg. cent.), then quenching in water and drawing at approximately 1300 deg. fahr. (705 deg. cent.), a product is obtained that is readily machinable and has good strength. High ductility, which is one of the essential requirements of high-quality malleable cast iron, is, however, absent. (Fred Grotts, Inspection and Metallurgical Engr. of the Caterpillar Tractor Co., Peoria, Ill., in *Transactions of American Society for Steel Treating*, vol. 7, no. 6, June, 1925, pp. 725–742, *eg*)

MOTOR-CAR ENGINEERING

Car with Engine of Fixed Radial Type Mounted at Rear of Chassis

DESCRIPTION of an experimental car built by the Julian Brown Development Corporation, Syracuse, N. Y.

The engine is a six-cylinder fixed radial air-cooled type and is mounted at the rear of the chassis. The crankshaft has two opposed throws and is supported in two main bearings, all of its journals being hardened and ground. Three connecting rods work on each crankpin, one blade and one forked rod being mounted on and concentric with the master rod. The camshaft is supported in a single bearing and carries only two cams. It is mounted above the crankshaft and is driven from the latter through an internal gear and two pinions. The drive for the generator, ignition unit, and oil pump is taken from the outside of the camshaft gear through an angular drive. The engine drives through a combination sliding pinion and planetary type of transmission giving four forward and two reverse speeds. An interesting feature of the car is the fact that instead of the conventional form a tubular steel backbone is used with two half-elliptic cross-springs secured to it at its ends.

There are three major parts to the tubular frame. The backbone consists of a $4^1/_2$-in. tube and this has two 2-in. cross-tubes pressed into it to support the body. The two transverse tubes are mounted on opposite ends of the main tube. Whereas the front spring is shackled at one end and pivoted at the other, the rear spring is pivoted at both ends, shackling being made unnecessary by the fact that the spring ends swing on the same radius as the axle ends. The ends of the rear spring are flat and rest between two oval blocks of celeron. (*Automotive Industries*, vol. 52, no. 23, June 4, 1925, pp. 988–989, 3 figs., *d*)

The Russian Tractor "Moto-Trud"

FOR various economic reasons it has been found that in Russia a tractor to be available for peasant agriculture must be cheap, extremely simple to operate, and applicable for a wide range of climatic and soil conditions of operation. The tractor "Moto-Trud" built by Kotliarenko Bros. in Russia has been designed to meet these conditions. As shown in Fig. 3, it is equipped with a horizontal single-cylinder two-cycle valveless crude-oil motor of conventional design. The motor shaft is vertical and runs in a combination-type ball bearing capable of taking both radial and thrust loads. The shaft operates on a worm-gear drive which in its turn connects to the axle carrying the driving wheels.

An interesting feature of this design is that the worm-gear drive is located in the crankcase and therefore operates at all times with plenty of lubricant and is largely protected from dirt and dust.

As shown in the drawing, the tractor has two large driving wheels in front, which carry about 96 per cent of the total weight of the machine, and a single smaller wheel in the back.

The tractor has no differential. Instead there are at both ends of the axle friction sleeves operating in connection with the driving wheels. The steering of the tractor is effected by throwing in the friction sleeve on the side toward which the tractor is to be turned. It is claimed that this gives the tractor a very large flexibility of steering. The usual change-gear equipment is likewise missing from this tractor. Instead the engine is provided with a centrifugal governor and the adjustment of the latter permits varying the speed from 1.5 to 5 km. (0.93 to 3.11 miles) per hr. The engine cooling is of the evaporation type.

The operation of the tractor has been simplified as much as possible. In front of the driver there are two wheels, the upper serving to change the speed of the engine and hence the speed of the tractor, and the lower acting as a steering wheel.

Because of the fact that the two wheels are entirely independent of each other, a large amount of flexibility in the steering can be

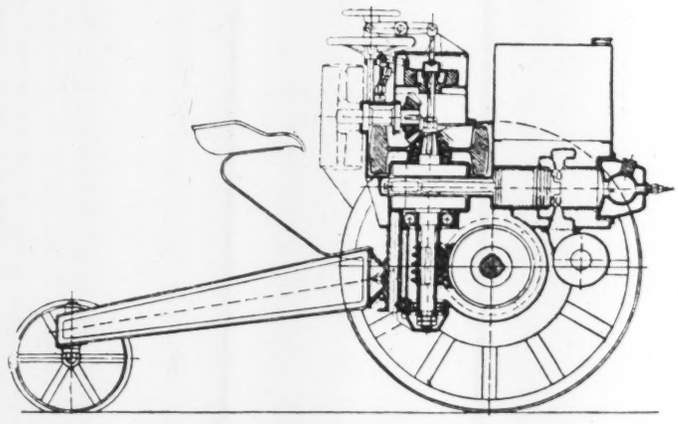

FIG. 3 RUSSIAN TRACTOR "MOTO-TRUD"

secured. The price of the tractor is stated to be 1200 rubles as compared with 1800 rubles for a Fordson tractor. (W. Jemtzeff, Engr., Berlin, in *Der Motorwagen*, vol. 28, no. 14, May 20, 1925, pp. 290–292, 1 fig., *d*)

NATIONAL DEFENSE

The Fleet and Aviation

IN DISCUSSING the relation of these arms of national defense the author, a rear admiral of the U. S. Navy, states that the (Navy) Bureau of Aeronautics has accomplished an enormous amount of work in the development, construction, and installation of planes and catapults on board ship. There are now installed on battleships and light cruisers in the fleet a total of 29 efficient catapults and 48 planes that are being operated from the catapults. In addition there are 82 planes organized in squadrons, all of the latest approved, tested, and accepted designs.

The author claims that there is a definite limit beyond which the airplane cannot be developed to do any work at all because it cannot get into the air. Well inside of this limit there is a point where the performance begins to fall off rapidly due to the fact that the ratio of the disposable load to the gross weight of the plane decreases until the point is reached when the disposable load becomes zero. The performance of airplanes is therefore limited to comparatively short distances from their bases of operation. It is the general consensus of opinion as stated by the author that a 30 per cent increase of the present performance is the best that can be hoped for within an indefinite time.

It is stated further by the author that for distant oversea operations it is necessary that the planes be transported to the area of such operations in carriers or tenders—in other words, in surface ships. (The author does not discuss at all the transportation of collapsible airplanes in large modern-type submarines.)

As regards the potentialities of aircraft in the operation of the fleet, they are said to be very great both before action is joined and

during battle. In scouting and observation aircraft have demonstrated their value and have become indispensable to the fleet in assisting the control of gun fire by observing and reporting the fall of shot ("spotting"). In gas warfare the use of aircraft may constitute a serious menace to ships. The value of the torpedoplane lies chiefly in the greater speed with which the attack is made. The functions of the lighter-than-air ship in the operation of the fleet are still in the investigation stage, and the experiments now being carried on should finally demonstrate whether or not the airship will be of real value as a unit of the fleet.

"In conclusion," states the author, "I beg you not to be deceived by dreamers of fantastic and impossible dreams of giant airplanes carrying tons of explosives and poisonous gases over thousands of miles and destroying whole fleets and cities in a moment, who unfortunately seem to have caught the public imagination and are misleading the people through the press and movies of the country. With their appealing slogans of economy to the effect that a thousand of such giant airplanes can be built at the cost of one battleship, they are seriously endangering our national security." (Rear Admiral Hilary P. Jones in an address delivered at the annual dinner of the American Society of Naval Engineers, Mar. 14, 1925, at Washington, D. C. *Journal of the American Society of Naval Engineers*, vol. 37, no. 2, May, 1925, p. 253–269, 1 illustration facing p. 253, *g*)

POWER-PLANT ENGINEERING (See also Steam Engineering: Pipe Losses in Steam Nozzles)

Water-Cooled Boiler-Furnace Walls

A GENERAL description of this type of equipment was given in MECHANICAL ENGINEERING, vol. 46, no. 11, November, 1924, p. 707.

Fig. 4 is an isometric view of the screen installation at Hell Gate. The side walls consist of 4-in. tubes arranged vertically on each side of the furnace and spaced on 7-in. centers. Each tube has two longitudinal steel fins welded on it, diametrically opposite each other, and when placed in the boiler furnace the fins overlap, thus presenting a continuous water-cooled surface to the radiant heat of the furnace. The lower portion of the tube is covered by fireclay tile for a short distance above the stoker. This extends along a horizontal line the entire length of the furnace. These brick are so placed in stoker installations along the line of the fuel bed, but are not used in pulverized-fuel furnaces.

The water in the tubes forms a part of the regular boiler circulation, the lower ends of the tubes being connected by headers leading to the mud drum. The upper ends of the side-wall tubes are connected to a header, which in turn discharges into the boiler drum through a special set of nipples and headers in front of the drum.

The water-cooled side walls not only replace practically all the brickwork in the side walls, but afford considerable protection to the front and rear walls by absorbing the heat which they reflect and thus lowering the temperature of the face of the wall.

A tendency at present is toward preheating combustion air. Pulverized-fuel firing in combination with air heaters makes possible very high ratings and produces naturally high efficiencies. This means a most intense heat in the furnace, making water-cooled walls practically imperative. With water-cooled walls installed under such conditions, the units may be kept on the line for long periods without any more liability of shutdowns than is caused by the boiler itself under present conditions.

In the discussion which followed, Geo. A. Orrok, Mem. A.S.M.E., stated that the boilers equipped with the device described in the paper and put into service in the plants of his company had given exceptionally good service. After nearly two years of operation, there seemed to be no sign of deterioration in either the tubes or the fins of the wall construction. The maintenance of this portion of the furnaces, he said, was only a small fraction of the erstwhile maintenance costs for brick walls.

He explained this in part by stating that, in the ordinary type of furnace, the lower rows of tubes ordinarily performed about 50 per cent of the work of evaporation of the water, because they received the hottest part of the flames and products of combustion. As a result, they scaled up rapidly and considerable erosion occurred. This meant deterioration and great cost for maintenance. The absorption of a considerable quantity of the heat from the products by the fins and tubes of the new walls took away a large percentage of the work done in the lower rows of boiler tubes, and reduced the scaling, erosion, deterioration, and maintenance costs of those tubes. (Paper before the Annual Meeting of the British Association for the Advancement of Science, in Toronto, Canada, by Col. Harlow D. Savage, Mem. A.S.M.E., Vice-Pres., Combustion Engineering Corp., New York, N. Y. Abstracted through *The Iron Age*, vol. 115, no. 23, June 4, 1925, pp. 1642–1643, 2 figs., *d*)

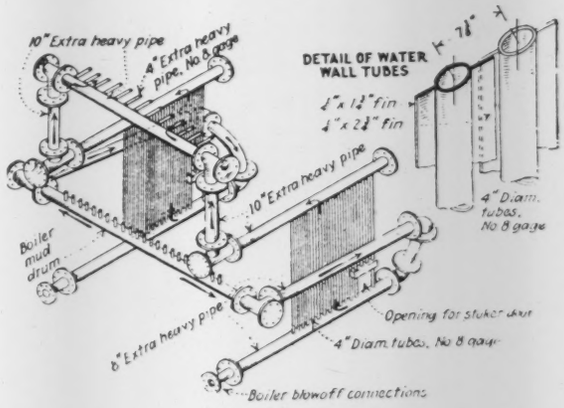
10" Extra heavy pipe
4" Extra heavy pipe, No. 8 gage
DETAIL OF WATER WALL TUBES
4" x 1¼" fin
4" x 2¾" fin
10" Extra heavy pipe
4" Diam. tubes, No. 8 gage
Boiler mud drum
6" Extra heavy pipe
Opening for stoker dust
4" Diam. tubes, No. 8 gage
Boiler blowoff connections

FIG. 4 ISOMETRIC VIEW OF FIN-TUBE SCREEN INSTALLATION DETAILS, SHOWING OVERLAPPING OF FINS

Excess Flue-Gas Temperature—Its Effect on Boiler Efficiency

ORDINARILY when a stoker is sold, the manufacturer guarantees that it will burn a certain fuel with stated efficiencies at various percentages of boiler rating. These efficiencies are based upon certain flue-gas temperatures which are supposed to be obtained with a type of the boiler under which the stoker is installed, and the contracts usually provide a flue-gas temperature increasing with the percentage of boiler rating.

The author does not believe that this is the proper procedure. He claims that quite often power-plant operators do not know what flue-gas temperatures should be obtained at various percentages of boiler rating. No definite standard has been established, and the temperatures which the boiler manufacturers will guarantee vary for different installations. In Fig. 5, curve *A* shows the range of flue-gas temperatures which the author has found to be the average for several of the better-known makes of boilers. Curve *B* was plotted from data taken from Marks' Mechanical Engineers' Handbook.

Above 100 per cent of boiler rating, curve *B* allows somewhat higher temperatures than curve *A* for the same boiler output. It averages about 25 deg. higher, with 35 deg. as the greatest difference at 250 per cent of rating. However, with modern forced-draft stokers or with oil firing, flue-gas temperatures fall considerably below. If they are above it is high time to look for leaky or faulty baffling or dirty tubes.

It should be borne in mind that there is no definite rule for determining the exact flue-gas temperature which should exist with any given percentage of boiler rating. There are so many different makes of boilers and different models of the same make. In general, flue-gas temperature varies somewhat inversely as the draft loss through the boiler. As the output of the boiler increases, the curve of draft loss becomes practically a straight-line increase up to 150 per cent of rating, after which the increment gradually becomes less. As shown in curve *A*, between 150 and 200 per cent of rating the increment is 55 deg.; between 200 and 250 per cent the increment has dropped to 46 deg., while between 250 and 300 per cent it is only 39 deg.

Boilers of the Stirling, Connelly, Badenhausen, Kidwell, etc., type generally have 0.10 to 0.15 in. less draft loss through the boiler than boilers of such types as B. & W., Edge Moor, Heine, Springfield, etc. On the other hand, these latter types generally have from 25 to 50 deg. lower flue-gas temperature for any given load.

For general all-around working conditions, temperatures as

shown in Fig. 5, curve *A*, may be applied to any and all makes of boilers having two or three passes. Temperatures with four-pass boilers are 50 to 75 deg. less for the same load, but the draft loss is much greater and for this reason four-pass boilers cannot be operated at as high percentages of rating as boilers with three passes. On this account four-pass boilers are not common, although they are very efficient.

In average boiler-room operation, with modern equipment, the average percentage of CO_2 in the flue gas is about 13 to 13.5 per cent. It should therefore be remembered that for every 100 deg.

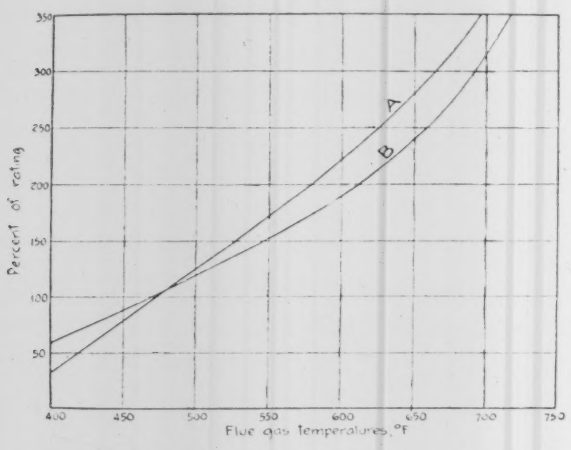

FIG. 5 RELATION BETWEEN FLUE-GAS TEMPERATURES AND PERCENTAGE OF BOILER RATING

the flue-gas temperature is permitted to exceed normal conditions there is a decrease in efficiency of 2 to 3 per cent. (J. R. Darnell, Mem. A.S.M.E., in *Combustion*, vol. 12, no. 6, June, 1925, pp. 432–434, 2 figs., *p*)

Testing Steam Engines by the Heat-Balance Method

DESCRIPTION of a method whereby the water rate of a reciprocating steam engine may be determined from a single set of instantaneous readings. The readings may be taken by any operating engineer and the results computed in less than ten minutes. Furthermore, by means of a set of charts previously computed to cover the operating range of an installation, results may be obtained in less than two minutes.

To illustrate the application of the method, the author considers an installation consisting of a Corliss engine equipped with a jet condenser and having the following specifications: Rated load 1500 i.hp.; normal speed, 1000 r.p.m.; steam pressure at throttle, 150 lb. gage; steam superheat at throttle, 90 deg. fahr.; vacuum at engine exhaust, 27.5 in. mercury. To check the performance of the installation a test was made, the results of which are fully described in the original article. These results may also be obtained from the set of charts shown in Fig. 6. This is an alignment chart which is designed to show steam consumption under all average operating conditions, as outlined in the article. As shown by the formula in the upper left-hand corner of the chart, calculations have been based on what may generally be considered an average temperature of water discharged from a condenser, i.e., 73 deg. fahr. This is the reason for the value 62.25, which is the weight of a cubic foot of water at this temperature. In the problem worked out with the chart we have:

H_t	= total heat of steam at throttle = 1200 B.t.u.	B
T_1	= temperature of condenser water inlet = 60 deg. fahr.	C
T_0	= temperature of condenser water outlet = 72.75 deg.	
H	= head of water over weir, in. = 10	D
$L/12$	= length of weir, in. = 27.2	E
C	= condenser discharge, cu. ft. per sec. = 5.2	H
I.hp.	= indicated horsepower = 650	I
Q	= condenser discharge, lb. per i.hp-hr. = 1800	J
$T_0 - T_1$	= temperature rise of condenser water, deg. fahr. = 12.75	K
W	= steam consumption, lb. per i.hp-hr. = 21.98	L

In this problem the values in vertical lines C and B are connected by line (1), which is extended through to vertical line A. Next, values in D and E are connected by line (2), which is extended through to reference line F. From here, line (3) is run to the same value in G, as already shown in D and extended through to vertical line H. From here line (4) touches the value in I and is extended to J. From J, line (5) touches K and is extended through to M, no attention being paid to where it crosses L. The final step is to draw a line (6) from A to M. The point where this line crosses L will give the ultimate answer in terms of pounds of steam consumption per indicated-horsepower hour. (Eugene Ogur, in *Power Plant Engineering*, vol. 29, no. 11, June 1, 1925, pp. 591–594, 2 figs., *dp*.)

RAILROAD ENGINEERING

German Diesel Locomotive with Fluid Transmission Gear

DESCRIPTION of a locomotive built jointly by the Magdeburg Machine Tool Manufacturing Co. (M. W. F.) and the Hanoverian Machine Construction Co. (Hanomag). The locomotive is rated

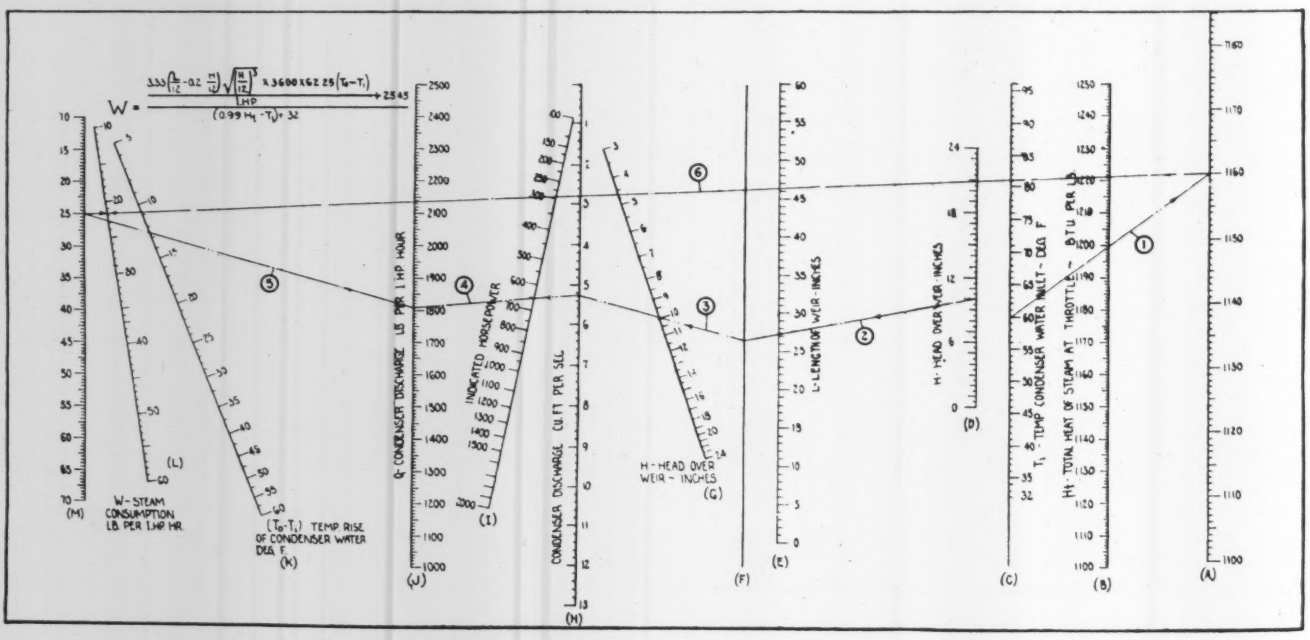
W = STEAM CONSUMPTION LB. PER I.HP HR.
(To-T1) TEMP. RISE OF CONDENSER WATER DEG. F.
Q CONDENSER DISCHARGE LB. PER I HP HOUR
INDICATED HORSE POWER
CONDENSER DISCHARGE CU. FT. PER SEC.
H - HEAD OVER WEIR - INCHES
L - LENGTH OF WEIR - INCHES
T1 - TEMP. CONDENSER WATER INLET - DEG. F
Ht - TOTAL HEAT OF STEAM AT THROTTLE - B.T.U. PER LB.

FIG. 6 ALIGNMENT CHART FOR DETERMINING WATER RATE OF PRIME MOVERS

at 120 hp., thus approaching the type T–3 locomotive of the Prussian State Railways. The most interesting feature of its construction is the Lauf-Thoma fluid transmission gear (Fig. 7).

This gear consists of a piston pump (primary) which converts mechanical energy into hydraulic, and one or two similar pumps (secondary) for reconverting the hydraulic energy into mechanical energy. In the locomotive here described there are two secondary pumps, as the purpose is to obtain a large drawbar pull rather than high speed. All the three pumps are of the same kind and size, designed to take care of the torsion moment of 500 m-kg. (3615 ft-lb.). The pump has radially arranged cylinders running in a cylinder block coupled to a drive disk, and operating against a rotating cylindrical guide disk of which the axis of rotation may be displaced eccentrically to that of the cylinder block. Each piston describes in the course of one revolution a stroke the length of which

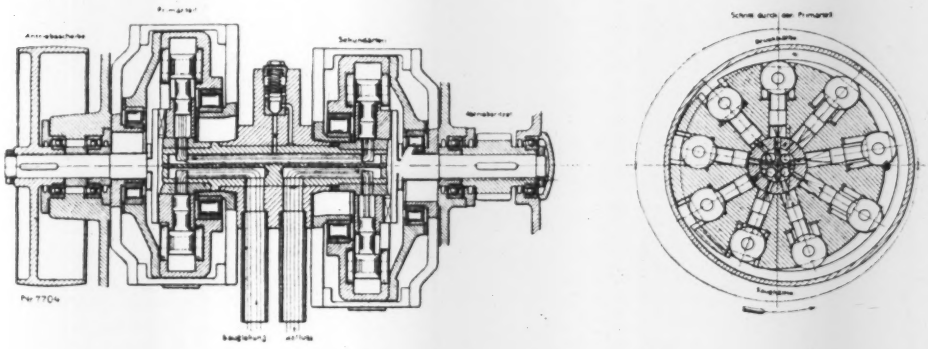

FIG. 7 LAUF-THOMA FLUID TRANSMISSION GEAR

depends upon the eccentricity of the guide disk. The central pin about which the cylinder block runs has ports for the inflow and outflow of the oil. During the suction stroke half of these ports are connected with the individual cylinders by special passages; when the pump reaches the dead center the cylinders are cut off from communication with the oil-admission piping. (*Hanomag Nachrichten*, vol. 12, no. 140, June, 1925, pp. 94–95, 2 figs., *d*)

RAILROAD ENGINEERING

2-8-4 Lima Locomotive for the B. & A.

BRIEF reference to the new locomotive built by the Lima Locomotive Works for the Boston & Albany Railroad Co., is of interest because it embodies an improvement in the wheel arrangement which offers a promise of lower stresses in track than those produced by other locomotives of equal weight. It represents a definite application of the findings of the Joint Committee on Stresses in Track.

Among other results obtained by this committee in the course of its work was the disclosure of the fact that the stresses produced in rails under the trailing wheels of locomotives are generally higher in proportion to the loads imposed by the wheels than those under the driving wheels. The explanation offered by the committee for the phenomenon is simple. Stresses in rails, as in all structural members acting as beams, are a function of the load and the span length, and as the span in the case of rails is the distance between wheel centers, stresses are higher under trailing wheels because of the relatively great distance of these wheels from the rear driver and the front wheel of the forward tender truck. In the third progress report of this committee, published in 1923, data are given on a test made with a heavy Santa Fe type locomotive which showed that the stresses in track produced by this locomotive were definitely lower than those produced by a locomotive of the same type equipped with a single trailing axle.

This suggestion has been carried out in the new Lima locomotive in which a load of 101,300 lb. is divided between two trailing axles spaced 102 in. center to center and with the front trailer axle 84 in. from the rear driving axle, whereas in the New York Central Class 8000, after which the new locomotive has been patterned, the single trailing axle carries a load of 58,000 lb. and is separated from the rear driving axle by a distance of 130 in. In other words, the later locomotive has been designed with a reduction of 12 per cent in the load per trailer axle and a reduction of 21 per cent in the maximum wheel spacing.

While the action of track under load is so involved that it is impossible to ascertain the actual improvement in track-stress conditions as a consequence of the changes embodied in the design of this locomotive, there is every reason to believe that an actual test would demonstrate marked improvements. Thus there is afforded another demonstration of the value of scientific investigation. (*Railway Age*, vol. 78, no. 27, June 6, 1925, p. 1375, *g*)

SPECIAL MACHINERY

A New Wire-Drawing Machine

DESCRIPTION of a wire-drawing machine made by the Vaughn Machinery Co., Cuyahoga Falls, Ohio, which has an individual adjustable-speed motor for each wire block. It is claimed that this eliminates the disadvantage of the single-speed multi-block type of wire machines in that with the former one machine could not be made to fit exactly every condition in drawing and to adapt itself to handle wire of various physical properties.

Compactness is secured by having one casting serve both as a frame and gear cover, permitting placing machines side by side on 5-ft. centers. The main housing, a box-type oil-tight casting, with motor and control, are mounted on a one-piece bed-plate and the entire machine is above the floor line, eliminating a pit and requiring only a light foundation. This, it is pointed out, is a distinct advantage when machines are to be installed on upper floors. The drive from the motor is through a flexible coupling to a worm gear running in oil and mounted in the main housing and connecting to the block spindle.

The machine is also equipped with a safety device by which it can be stopped very quickly. It is stated that should a workman be caught in a loop of wire he cannot avoid striking the safety bar, which will stop the block by applying a dynamic brake to the motor before the man can be injured. (*The Iron Age*, vol. 115, no. 23, June 4, 1925, p. 1645, 2 figs., *d*)

SPECIAL PROCESSES

The Manufacture and Heat Treatment of Large Forgings

A PAPER written in an endeavor to indicate some of the procedures and precautions necessary in the manufacture of large steel forgings as distinguished from those employed for forgings of ordinary size.

The art of forging large masses of metal was developed in the production of guns, projectiles, armor plate, and engine parts for naval vessels. The second important impetus was furnished by the improvement and growing use of large turbine units.

The successful manufacture of large forgings depends on special open-hearth practice, the first essential being the production of a sound ingot. The ingot is allowed to solidify before stripping and is then usually charged hot into the forging furnace. It is unwise to allow a large mass of metal of such coarse crystalline structure as that existing in the ingot to cool too rapidly. Ingots of certain compositions are annealed.

The largest forgings are usually pressed rather than hammered, and the success of the forging depends largely upon the correct forging temperature. The finishing temperature is an important factor since finishing at a low temperature by a series of squeezes evenly distributed over the surface breaks up the coarse grain growth which would otherwise be found in the finished forging.

The sequence of forging operations is illustrated on several examples, such as a forging for a large rotor-field shaft or a turbine spindle forging.

Many forgings of today are hollow, such as gun hoops, cylinders, turbine drums, and various large rings. In the manufacture of such pieces, the top and bottom scrap must first be cut from the

ingot. This may be done either in the machine shop or beneath the press. The longitudinal hole is made in the billet either in the machine shop, by hot coring, or by hot punching under the press. In any case the comparatively weak central portion of the ingot is removed.

The billet with an axial hole is then supported horizontally beneath the press, on a roughing mandrel. It is expanded using a special die in order to work the metal circumferentially, and the diameter of the bore is increased. Large mandrels are used as the cylinder is expanded. The forging may be supported by the mandrel which rests on supports. For the finishing operations a V-die is used as a base, and the mandrel is not supported. An illustration in the original article shows a cylinder on the finishing mandrel. The loose scale in the bore must be removed continually to prevent deep pitting. Care must be exercised on a thin-walled cylinder that it remains cylindrical.

All large forgings require some heat treatment to remove internal strains and to insure homogeneity. Each type of forging calls for special treatment, and the proper heat treatment for a forging depends upon its size, shape, composition, the physical properties required, and its use.

It is sometimes difficult to prevent warpage or distortion in large and uneven masses of metal. Heating and cooling should be as uniform as possible. The forging should be well supported in the furnace to prevent this trouble. For this reason gun forgings and long shafts are suspended vertically. On quenching, the entire piece should be dipped as rapidly as possible.

Many large forgings, both of carbon and alloy steels, are successfully given treatments, including one or more quenching operations. Turbine disks of carbon, nickel, and chromium-nickel alloy steels show superior physical properties by this method of treatment. Large high-carbon alloy-steel rolls are hardened to over 110 sclerescope hardness. Before giving large masses of metal a quench, it is best first to bore the forging to relieve the weak center line of the ingot, and thus increase the effectiveness of the quench.

The utmost care is necessary in the testing of large forgings to be sure that the condition of the metal at all parts subject to strain is indicated. In a large forging no single test bar can represent the average condition of the metal. The center line of the ingot is the weakest part of the forging. The smallest sections of the forging will show better properties than the larger portions, because they have received more mechanical work and are also more affected by the heat treatment.

To be sure of the solidity of the piece, and the absence of shrinkage cavities or other openings, there is nothing quite as satisfactory as the boring of the piece and the inspection of the bore. All large rotor-field shafts, turbine-spindle shafts, and similar objects should be bored, and the bore inspected for cracks and other injurious defects that may have been produced by forging and heat treatment. The bore should be smooth and carefully examined with a bore searcher. These are of various forms, either a simple light and mirror, or a series of reflecting mirrors with a telescope for magnification. Periscopes are made in the form of sectional tubes, carrying their own lights, and magnifying the surface about two and one-half diameters. Any small imperfection may be removed by enlarging the bore. If the bore is clean, we may be reasonably sure of the rest of the forging.

An English company manufactures a so-called "clink detector." This is attached to the forging during cooling, and is somewhat similar in action to the seismograph, although not at all similar to it in construction and design. It records any shock received by the piece, which might be caused by a clink or the internal cracking of the piece due to the giving way of the metal to some unbalanced strain. [Compare Mechanical Engineering, vol. 47, no. 7, July, 1925, p. 565.] (A. O. Schaefer, Asst. Engr. of Tests, The Midvale Co., Nicetown, Pa., in *Transactions of the American Society for Steel Treating*, vol. 7, no. 6, June, 1925, pp. 699–717, 16 figs., *dpA*)

STEAM ENGINEERING

German Impressions of Steam Engineering in the U. S. A.

The author, a vice-president of the German General Electric Co., found a strong tendency toward the employment of higher pressures (20 to 25 atmos.) in steam power plants in the United States, which he ascribes in part to the use of high-priced coals or high ground-rent charges. The load factor in American central stations appears to be in general materially better than in Germany. He considers as characteristic of the American manner of thinking an expression of a leading engineer, who, while uncertain that the installation of high steam pressures would bring material economies in his central station, nevertheless decided to put in a high-pressure boiler and gave the following explanation for his decision: "We are a big concern and consider it our duty to contribute to the development of engineering." In another plant a dust collector was being installed, although it was not considered a very economic device. The management explained its installation by saying that they got a living from the public, which took an interest in such apparatus, and they considered it valuable to please the public. With such a broad manner of thinking prevailing in the land, manufacturers have more impetus for trying out new things than they have in places where only economic considerations have force and the price range is very narrow. (Friedrich Münzinger, Berlin, in *Zeitschrift des Vereines deutscher Ingenieure;* serial article partly abstracted in vol. 69, no. 23, June 6, 1925, pp. 773–778, figs. 7–13, *g*)

Pipe Losses in Steam Nozzles

In this paper an attempt is made to deal with a main type of loss in nozzle expansion. This is called the "pipe loss," as it is analogous to that occurring in a straight-axis pipe of cross-section as in the nozzle. The treatment ignores all other actions peculiar to nozzles but alien to straight-pipe flow. Thus convergence effects, jet compressions or contractions, axial curvature, free expansions, and their influences on the total nozzle losses are considered extraneous to the point at issue, although no doubt important in different cases and in their ways. In general, then, the loss considered is only a portion of the whole. It is nearly the entire loss in the elementary nozzle types; it is a considerable proportion of the whole in practical impulse nozzles, but only a moderate portion in purely convergent forms having axial curvature, as in a Parsons blade.

The authors derive a general expression for the space rate of energy loss per unit mass of flowing fluid. This expression consists of two separate terms which may be referred to as the "viscosity" and "compressibility" terms; the former marks an energy loss in maintaining the régime established by the viscous forces, while the latter arises from wave production. Each has in general its own range of special influence.

In the consideration of a closer meaning of these terms a distinction is drawn between nozzles that really act as pipes at all parts of their length and those that do not. Pipe flow as herein understood infers that all sections of the passage run full. In nozzle expansions this is generally the hope but not always the fact. The jet expansion is a peculiar phenomenon, and will not necessarily proceed along a certain route because that is mapped out by the nozzle profile. Breakaway of the jet from the wall is quite common and, indeed, characteristic of certain sections. Thus a vena contracta produced by faulty convergence, a curvature of axis, a recompression in a divergent outlet, or severe irregularity of bore provide conditions in which a nozzle is not a pipe. It is, however, in such conditions that experiment gives evidence of the existence of wave actions in the fluid, so that in such cases we could not assume the negligibility of the loss factor under discussion. These conditions, however, do not enter into our present considerations since we are here wholly concerned with fully controlled expansions. The other cases belong to the category of free-expansion effects.

There is no evidence that the compressibility term has any real importance in nozzles that definitely control the jet. There is some evidence that it is important where the shape is less effective.

Considering the nozzle in its equivalence to a straight length of effective pipe, the author proposes a simplified form of the equation above referred to wherein the compressibility factor is left out entirely. He claims that this gives a sufficiently general expression applying even for high-speed flow.

The only really direct data in support of the statements made regarding the space rate of energy loss per unit mass of flowing fluid are provided by the friction constants previously given (On the Losses in Convergent Nozzles. Proceedings North-East Coast Engineers

and Shipbuilders, Feb., 1921) by the authors for the case of a straight-axis convergent-parallel nozzle of machine finish. From a consideration of the equation giving the rate of friction loss in the straight tail length of the convergent-parallel nozzle and the general equation for the space rate of energy loss per unit mass of flowing fluid, it is found that a coefficient c in the former equation represents the unknown function φ in the general expression, and that moreover this coefficient is not constant but has a falling value practically up to the acoustic velocity. The general evidence is therefore against the inclusion of the compressibility term in the general law of loss for the type of expansion encountered in these kinds of nozzles.

It would seem, then, that for the case of a machined nozzle we could write the rate of energy loss as

$$\frac{de}{dx} = \frac{v^2}{2g} \times \frac{p}{A} \times 0.00127 \left(\frac{T_1^{3/2}}{P_1} \times R \times \frac{p}{A} \right)^{1/8} \quad \ldots\ldots [18]$$

where e = energy loss, ft-lb. per lb.
x = length, in.
v = velocity, ft. per sec.
p = perimeter, in.
A = nozzle area, sq. in.
T_1 = initial temperature, deg. fahr. abs.
P_1 = initial pressure, lb. per sq. in. (abs.)
R = function of k and r expressed in Equation [16] of the paper and plotted in Fig. 4 of the paper.

The form of Equation [18] is general and rational. The coefficient and index, however, have been derived from one set of nozzle tests only. They are probably subject to change with surface, and, consequently, as the equation stands, it can only represent the case of "machined" nozzles.

In the discussion which has resulted in Equation [18], the examination has been based entirely on the fundamental theory and has utilized figures from nozzle tests only. It is now desirable that a comparison with the established facts of ordinary pipe flow should be carried out since, if agreement can be shown to exist, the figures available from this latter source become of some service.

The fullest investigation of resistance at the lower speeds is probably that carried out by Stanton and Pannell who employed smooth brass pipes varying from 0.3 cm. to 12 cm. in diameter, and speeds up to about 5000 cm. per sec., using both air and water. This work has been carefully analyzed by Lees, who, using other data in conjunction, has given an expression for the resistance per unit area which meets the facts very closely.

Calculations made by the authors show that there is a fair difference in magnitude but a similar order of increase. To expect exact equality would be to assume identical conditions, which is hardly possible. To both cases the description "smooth brass pipes" could certainly be applied; but considering the possibility of some real difference in this respect, the wide change in speed of flow, the different fluid, and the uncertainty of the viscosity value, the agreement may be passed as fairly good. It shows that the coefficients for pipe flow are, at least, a guide to the corresponding figures for nozzle flow, and, when the impossibility of specifying the exact surface condition is taken into account, the guidance is probably quite satisfactory.

The generality of the whole process of examination is fairly well confirmed by the outcome of the above comparison. Hence there need be little reluctance in applying the methods to speeds beyond those involved in the analysis so far, i.e., beyond the acoustic velocity. These higher speeds occur, of course, in the divergent types of nozzles. The agreement of such cases with the general method is shown, with fair clearness, by the application of the constants defined by convergent-nozzle operation to the observed results with divergent forms.

The effect of surface conditions is considered next. This part, though of great interest, is not suitable for abstracting. It would appear, however, that for an ordinary turned brass nozzle the coefficient c has a value of about 0.0050. In nozzles of rectangular section with highly polished surfaces c has a value of from 0.0035 to 0.0040. In the same nozzles with the surfaces spoiled by roughing with a file, the value of c rose to 0.0080 and the authors show that c in the nozzle formula varies approximately in a manner similar to that of the factor f in the hydraulic formula for the head lost in pipe friction.

In this connection interesting data of tests carried out by A. Cameron on the authors' apparatus are mentioned. In these tests an unexpectedly high value was found on a cast nozzle. The reason for this is not quite clear.

Part 2 deals with the controversial matter of the form of nozzle efficiency curves, whether the efficiency of convergent-parallel types increases or decreases with speed of efflux. It is shown that when the pipe loss alone is considered the efficiency (or velocity coefficient) must increase with speed within the turbulent range.

Part 3 of the paper is concerned entirely with the reduction of the main loss equations to forms and graph systems suitable for ready calculations. Some accuracy is no doubt thereby sacrificed, but the advantages more than outweigh the degree of uncertainty introduced. The attention of those whose duties involve the estimation of nozzle losses may be directed to this section especially. Fig. 5 and Figs. 8 to 17 of the paper, together with Equations [31] to [36], represent the essentials of this treatment of calculation methods. (Prof. A. L. Mellanby and Prof. W. Kerr in *The Journal of the Royal Technical College*, no. 1, Dec., 1924, pp. 67–102, 17 figs., *etA*)

TESTING AND MEASUREMENT (See Power-Plant Engineering: Testing Steam Engines by Heat-Balance Method)

TRANSPORTATION

Store-Door Delivery on the Boston and Maine Railroad

WHILE this system is commonly used in England it has not been so far used in the United States, but the Boston and Maine Railroad has announced that it will establish a system under which merchandise will be picked up at the door of the shipper and delivered at the door of the consignee as a complete transportation service utilizing railroad and motor truck. This will be particularly used for extending the less-than-carload freight service. At the outset it is proposed to establish the plan at Boston, Lowell, and Lawrence, Mass., and to extend it as it proves its value.

The Boston and Maine is also considering the use of motor-truck transport for less-than-carload shipments between Boston and Lowell and between Boston and Lawrence in each direction. This service will include the handling by motor truck of merchandise to and from railroad terminals at most of the intermediate points on these lines. The great bulk of the shipments between Boston and Lowell and Boston and Lawrence, however, will continue to move by rail, with the direct collection and direct delivery at the three towns to expedite terminal movements. The new plan will not affect carload shipments. It is proposed to contract with existing trucking companies for the service wherever practicable, rather than to engage in wasteful competition. Use of the new facilities by shippers and by consignees will be optional.

The study of traffic conditions which preceded announcement of the new plan disclosed the fact that 43.3 per cent of less-than-carload tonnage moving to and from Boston and Maine freight houses in 1924 was handled by horse and wagons. The wagons constituted 40.5 per cent of the vehicles so engaged. These studies showed that the average load per vehicle was only 838 lb., although with the wagons there were used trucks as large as 10 tons capacity. By the new system of organized cartage, simplifying movements and increasing the average load, the work can be performed by a considerably reduced number of vehicles. The extent to which this will relieve congestion in downtown Boston is indicated by the fact that 77 per cent of the hauling to and from the Boston and Maine terminals last year was within two miles of the North Station. (*Railway Review*, vol. 76, no. 21, May 23, 1925, p. 943, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

Standards for Graphical Presentation

THE American Society of Mechanical Engineers has requested the American Engineering Standards Committee to undertake the preparation of national standards for graphical presentation, and the latter has authorized the appointment of a representative special committee to consider both the questions of sponsorship and scope.

Graphical presentation of statistical and quantitative data belonging to the most varied fields of human endeavor has made enormous progress, particularly during the last decade. Charts, diagrams, or graphs put life into the dullest of statistics and make the facts "stick out" and tell their own story at a glance to the busy executive.

Organization and process charts, "pie" and "bar" diagrams, curves showing the increase in sales or in population, relative costs, etc., all have their usefulness, and usually there is a best which should become the "standard" way of drawing each of them. New diagrams and graphs of all sorts appear almost daily in all kinds of periodicals, books, and miscellaneous publications. It seems very desirable to compare notes and to get the consensus of opinion of competent judges in order to lay down the basic ideas and safe rules to be followed by the ever-increasing number of those who have to prepare charts.

In 1914 The American Society of Mechanical Engineers organized a joint committee to develop standards for graphics of various kinds. This committee was made up of representatives of 17 organizations. It published its first and only report in 1917. This report was so favorably received that it has been reprinted several times. In 1921 the Management Division of the Society took over the work, enlisting the coöperation of the Society of Industrial Engineers, the American Statistical Association, and the Taylor Society. These groups have decided that the work should now be so broadened that national standardization could be brought about. Hence the request to the American Engineering Standards Committee, the national clearing house for industrial standardization whose procedure insures that the desired consensus of opinion, will be effective in producing results which will be of benefit to all interested parties.

Work of Standardizing Colors for Traffic Signals Nearing Completion

THE work involved in bringing about national uniformity in the use of colors for traffic signals is nearing its completion, full agreement has been reached upon the various technical details, and the code is about to be published, according to an announcement of the American Engineering Standards Committee.

The work has been carried out by a sectional committee on which all interested groups are represented, including more than thirty national organizations, under the leadership of the American Association of State Highway Officials, the Bureau of Standards, and the National Safety Council.

The code covers the use of luminous and non-luminous signs and signals in connection with highway traffic, including moving and flashing signals, and the use of lights, semaphores, and other signaling devices on vehicles.

The three colors agreed upon for primary traffic-control signals are: *red*, for stop; *yellow*, for caution; and *green*, to proceed. To quote from the code:

> The use of red is proper as an indication to stop and to then proceed if conditions are favorable, as, for example, when "stop" and "proceed" regulations are in effect.
>
> Yellow is appropriate when caution is to be exercised without stopping, as for partial street obstruction, so as to reserve red for a stop signal.
>
> Green shall be used as an indication to proceed.

The code gives concise qualitative definitions of these three colors, as well as of colored glasses and of the colors recommended for non-luminous signs. These recommendations are based on the findings of three sub-committees which collected exhaustive data on the present diversity of highway signals and made a thorough study of the questions relating to visibility of colors and also to signboards and other non-luminous highway signals.

Careful experiments showed that the red signal lights were most easily distinguished from other colors at a distance and required the lowest light intensity for unmistakable recognition. On the average, a red light of 75 candlepower could be identified at 600 ft., while a green light had to be of 250 candlepower, a yellow 750, and a blue light 1000.

It is of paramount importance that the use or significance of all these signals become so familiar that they will produce an unconscious but correct and effective reaction, as it is doubt in the correctness of signal interpretation that leads to uncertainty in motions and to accidents.

Standardization of Drawings and Drafting-Room Practices

THE American Engineering Standards Committee has been requested by The American Society of Mechanical Engineers to authorize the organization of a Sectional Committee whose duty it would be to develop standards for drawings and certain drafting-room practices. The Society has signified its willingness to act as sponsor or joint sponsor for this project.

At the Main Committee meeting of the A.E.S.C. on June 11, 1925, the Chairman was authorized to call a general conference or to appoint a special committee to consider the proposed standardization.

Drawing is the universal graphical language of the industrial world. It has its "grammar" and uses varied forms of expression and varied styles, all matters of importance on which it is evidently advantageous to have general agreement. As an example of the present-day diversity, not less than 23 different methods exist to represent the most common standard American form of screw thread, and this is only one among the innumerable details considered in mechanical drawing.

Among the organizations in this country which have been carrying on standardization work in this field and have prepared manuals of unusual significance, are: The Bureau of Ordnance, U. S. Navy Department; the General Electric Company; Kempsmith Manufacturing Company; Reed-Prentice Company; Barber-Colman Company; Gurney Ball Bearing Company; Walworth Manufacturing Company; Union Tool Company; The Jeffrey Manufacturing Company; Connersville Blower Company, and B. F. Sturtevant Company.

These drafting-room manuals are more or less elaborate and complete as to the field covered by the standard practice. They standardize the conventions used on drawings, give the sizes of paper or cloth used, the size of style of lettering and grouping of notes, the arrangement of views, dimensioning, methods of expressing tolerances, instructions for alterations, classification of drawings and much other valuable information.

What is needed now is to come to a definite understanding as to the best practice to be recommended as a national standard.

Specification for Wire Rope

THE most important paper in its field that has been issued in several years is Circular 208 of the Bureau of Standards, United States Government Master Specification for Wire Rope. The paper is made up of eight major sections dealing with types, material, and workmanship, general requirements, detailed requirements, inspection and tests, packing and marking, additional information, and general specifications.

It contains 28 line drawings and halftones illustrating types of rope, methods of measuring rope diameter, application of seizing, clips, and other fastenings for wire rope. The properties of the

different types of rope are set forth in tables which give all the important data in very compact form.

This circular has been prepared, after careful study, by the wire-rope committee of the Federal Specifications Board, the chairman of the committee being H. L. Whittemore, of the Bureau; and was officially promulgated by the board on June 1, for the use of the departments and independent establishments of the Government in the purchase of wire rope.

Copies of this circular are now on sale at the office of the Superintendent of Documents, Government Printing Office, Washington, D. C., at 15 cents each.

Recommended Minimum Requirements for Masonry Wall Construction

A FIFTY-SEVEN-page report on Recommended Minimum Requirements for Masonry Wall Construction has recently been issued by the Department of Commerce. The report, consisting of three parts, was prepared by a Committee of architects and engineers organized by Secretary Hoover in 1921 to draft recommended uniform building laws for adoption by cities and states throughout the country.

Part I describes the Committee's procedure in obtaining information bearing on this subject; preparing a report in tentative form and submitting it to those interested for criticism; and revising its recommendations after consideration of the constructive reviews thus obtained.

Part II presents a set of building-code requirements for the regulation of masonry wall construction recommended for adoption or adaptation by those writing or revising building codes. These sections cover the quality of materials, maximum stresses for which masonry should be designed, matter of workmanship, and the height and thickness of unstayed masonry walls both bearing and non-bearing. In general, the Committee's investigations disclose that thinner walls than those usually required in building codes are safe except under abnormal conditions of loading, wind pressure, or seismic disturbances.

Extensive tests of the fire resistance and crushing strength of various masonry materials and combinations were made at the Bureau of Standards and other places as a preliminary to the Committee's report on this subject. Summaries of these investigations and much other valuable information on masonry wall construction not otherwise obtainable in concise form are given in Part III of the Report. This part also is intended as an explanation of the code requirements advocated in Part II with the thought that their adaptation by code-revision committees and their administration by building officials will thus be considerably facilitated.

Previous reports of the Committee have received wide circulation and have been utilized in many cities and states. It is expected that the report on Recommended Minimum Requirements for Masonry Wall Construction will be welcomed by architects, engineers, and builders. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. for 15 cents per copy, currency, or money order.

University Fellowships Offered for Study of Special Problems in Safety Education

THE Safety Committee of the Society asks that notice be given of the fact that The National Bureau of Casualty and Surety Underwriters offers for the academic year 1925–1926 three graduate university fellowships of $1000 each for the study of special problems in the field of safety education. The subjects are:

1 The grading of subject-matter for safety instruction in the elementary schools
2 The preparation of a course of study in safety education for the use of normal schools, and
3 A study of the relative importance of positive vs. negative methods of instruction.

These fellowships are offered in order to secure expert solutions of problems which confront the education section of the National Safety Council in its work; a work which is also financed by the National Bureau. The first problem is that of adapting the subject-matter of safety instruction in detail to the needs of the elementary schools; the second is the general problem of organizing methods of teaching safety, and the third is a psychological research into the question of how far there is danger of developing a fear complex in the child and into the more general question of the relative desirability of positive and negative methods of approach in this field.

For those who are uninformed it may be stated that the work of introducing safety education into the schools is now so well under way that it is safe to predict that the subject will eventually, or even shortly, find a place in the curriculum of every progressive school; and this research has been undertaken, and other researches will be undertaken in the future, in order to make sure that the work is done along fundamentally right lines.

Applications should be sent to Albert W. Whitney, Associate General Manager and Actuary, National Bureau of Casualty and Surety Underwriters, 120 West 42nd Street, New York City, and should be accompanied by pertinent information with regard to the experience and purposes of the applicant, references, and, what is particularly important, a detailed plan of how he would propose to go to work to solve that one of the three problems listed in which he is particularly interested. The applicant should also state at what university he would prefer to carry on his studies. Mature students who have had some years of teaching experience are desired, and it is presumed that students will wish to offer the results of their research as theses for the degree of Doctor of Philosophy.

Standardization of Color Markings for Compressed-Gas Cylinders

THE Industrial Accident Commission of California recently requested the American Engineering Standards Committee to undertake the standardization of color markings for the identification of compressed-gas cylinders. It has been proposed that this suggestion, together with the proposal of the War Department for the standardization of valve threads for compressed-gas cylinders, be the subject of a general conference of all interested groups to decide what action, if any, should be taken. In view of representations to the Committee by representatives of the Compressed Gas Manufacturers' Association and the International Acetylene Association that the producers were not at present prepared to enter into such an undertaking, the A.E.S.C. decided not to assemble such a conference at the present time. This action is in accordance with the general policy of the A.E.S.C. that it is not itself an initiating body and that work is undertaken under its auspices only when the attitude of industry is sufficiently favorable to make it reasonably certain that national standardization, that is, a real national consensus, can be brought about. For this, the active coöperation of the producer groups is manifestly necessary.

The American Mining Congress now a Member of A.E.S.C.

THE membership list of the American Engineering Standards Committee has recently been increased with the admission of the American Mining Congress, which becomes now a regular member body with one representative, Mr. James F. Callbreath, and one alternate, Col. Warren R. Roberts.

The American Mining Congress is extensively engaged in standardization activities, having an entire division of the Congress devoted to the subject. Under the division are two general committees, one on coal mining, and the other on metal mining. Under the first of these there are operating 25 committees and sub-committees, and under the second 21 committees and sub-committees. Working on these various committees are several hundred engineers.

The Congress was already taking a very active and important part in the work of the American Engineering Standards Committee. For example, it holds sponsorship for nine standardization projects in the mining field.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

"Engineman" or "Engineer?"

TO THE EDITOR:

I note the short paragraph on page 303 of the April issue of MECHANICAL ENGINEERING entitled "Engineman or Engineer," relating to the adoption by the United States Civil Service Commission of the term "engineman" for all operators of stationary engines, etc.

That the Commission has been misinformed and has perpetrated a grave injustice to the thousands of operating engineers in this country, cannot be denied. To begin with, our first engineers were of the "operating" variety, and needed very little education in their day compared with present requirements. With an advance of the art we find engineering divided into two classifications, military and civil, the two words clearly explaining their respective spheres. The next step was the division of civil engineering into two classes: civil, or the construction of public works, and mechanical, covering the mechanical arts, etc. Briefly, these two classes of civil engineering have again been divided into hydraulic, sanitary, electrical, etc., to say nothing of the much-abused term of "efficiency engineer," covering everything in general and nothing in particular.

If any one will trace back engineering he can easily satisfy himself that "professional engineers," meaning, probably, college graduates, are of comparatively recent date. Then why this attempt by one class of engineers to deprive another of its rightful heritage? And incidentally, how far will this classification go? Will it not eventually mean that all operating engineers will be so classified, even the "chief" of a super station? Think of it! the "chief engineman" will hire a real (?) engineer just out of college to assist him with some of the detail duties he is too busy to bother with.

It has been charged that the ruling is a discrimination in favor of the college graduate, as an engineman will not be considered eligible for any supervisory positions. Plainly speaking, "Once an engineman, always an engineman."

But can the mechanical engineers afford to see "class legislation" degrade and drive from the operating field the men who have so loyally stood behind the designing engineers? for certainly some plants have needed real operating engineers to pull them through. Many of the leading members of the Society never attended college nor received a "degree," but is the Society the worse because of them?

The Commission arrived at its decision after obtaining "unanimous opinion of classification experts, engineering societies, and individual personnel men that the term 'engineman' was more suitable." Who are the "classification experts, engineering societies, and individual personnel men" who made this momentous decision? No one can find out.

It would certainly be more patriotic and, may I say, "good business" for the Society to boost the operating man, and not countenance any attempt to make his work just a "job." The interests of the designing, construction, and operating engineers are too closely related to permit any "petty politics" to interfere with the harmony which now prevails.

Why not get the opinion of some of our members who have no "sheepskins?"

WARREN D. LEWIS.[1]

Brooklyn, N. Y.

[1] Operating Engineer of Power Plant, Metropolitan Life Insurance Co., 1 Madison Ave., New York, N. Y. Assoc-Mem. A.S.M.E.

An American Tribute to the Unknown Soldier of Czechoslovakia

TO THE EDITOR:

The American delegation to the First International Scientific Management Congress held in Prague last summer, just before leaving the city, made a pilgrimage to the grave of the Unknown Soldier in a crypt in the ancient Town Hall and placed on it a wreath. Those present—for the most part members of the A.S.M.E. and their families—will always carry memories of the occasion.

In going over some papers recently returned to me from Prague I came across the words spoken by Dr. Harlow S. Person, Managing Director of the Taylor Society, representing the American Committee, as follows:

> Son of Czechoslovakia, brought here to rest forever, and forever to receive, on behalf of brothers who have made the supreme sacrifice, the reverence of a grateful people: May we, a small band of pilgrims from a far country, offer you this testimonial of *our* reverence; and may we believe, now that you have become one of the immortals, that you no longer belong exclusively to one people, but belong in part to all peoples, and belong in part to us!

Because of the simplicity of these words, their elevation, and as an expression of the attitude of the American people toward the newly organized Republic of Czechoslovakia, they should find a place in the records of our Society. Hence this note.

M. L. C.

Philadelphia, Pa.

Pioneers Needed in the Field of Four-Dimensional Engineering

TO THE EDITOR:

The writer has read with interest the presidential address of Mr. Fred R. Low, entitled Power Resources, Present and Prospective, as published in MECHANICAL ENGINEERING, January, 1925.

Quoting from the above address, Mr. Low says: "...but in the economy of nature this process [of separation of the C and O in CO_2] is constantly going on, not with the noisy demonstration of prodigious effort, but quietly, in the delicate structure of a green leaf waving in the sunlight."

The foregoing suggests comment. Why is it that the engineering profession has so long continued in its neglect to study the engineering structures of nature? The very limitations which we now encounter in regard to increasing the efficiency of our prime movers, as well as all engineering structures in general, are a result of following all too blindly a limited system of engineering thought and construction far less comprehensive than that on which all natural things as well as the entire universe are builded.

It should be noted here that the living constructions of nature are of the flexing type, able to bend and twist as required, and not of the rigid type that man has been wont to follow in his attempts at energy conversions with their correspondingly low efficiencies.

The engineering in nature and the universe follows one and the same code of rigidly mathematical laws, physical events occurring in a four-dimensional framework having three dimensions of space and one of time.

Why, then, have we been restricting ourselves in the design of engineering structures to a two-dimensional basis as regards spatial characteristics, for such is the nature of nearly all engineering structures of man to date? For although an engineering structure may apparently appear to be three-dimensional in space, on analysis it will be found that its whole design is developed merely on the basis of the principles of plane geometry. After studying the mathematics of space for generations we are still limiting ourselves to the use of two-dimensional elements in design. Could anything be more ridiculous?

How can we ever hope to attain the efficiencies found in nature

in regard to energy conversions, when we fail utterly to avail ourselves of the same methods of construction as are found in natural objects which live and grow and are designed on a four-dimensional basis?

The engineer of the immediate future who desires to assist in breaking the shackles which bind present-day engineering development must obviously get the true vision of engineering as expressed in nature and the world. He must study and apply the mathematics which comprehends the movements of particles in space, namely, spatial analytic geometry, quaternions and the relativity theory. "Quaternions," says C. J. Joly in his manual on the subject, "lend themselves to the treatment of projective geometry quite as readily as to investigations in mathematical physics and in metrical geometry."

The writer has satisfied himself experimentally that a virgin field of endeavor beckons the four-dimensional engineer, and can conceive of no greater service that he can render his profession than to continue to serve as a pioneer four-dimensional engineer.

CLIFFORD B. CRONAN.

Shelburne Falls, Mass.

What Is an Engineer and How Much Pay Should He Receive?

TO THE EDITOR:

Referring to Dean Kimball' seditorial in the June issue, of MECHANICAL ENGINEERING, and the caption: "What is an engineer, and how much pay should he receive?" the writer would say that the term "engineer," like that of "doctor," is being used by a great many who have no special training or natural ability to entitle them to the use of either term. From a business man's standpoint, it is his opinion that the methods of instruction in the present-day colleges are responsible for the great number of failures in the engineering world.

Recently in a small job of designing a sketch of a certain bushing was handed to a graduate of a state university who had diplomas in both mechanical and electrical engineering. This bushing, because of its large outside diameter and small inside diameter, carried excess metal, making a casting very much overweight for the duties it had to perform. The young engineer was instructed to design this casting, coring out the sides to reduce the weight. It was explained to him that the bushing would be too heavy unless it was considerably reduced in weight. After several hours of work he presented to the shop foreman a beautiful drawing of two bushings, one to go inside the other. When asked why he had made two bushings instead of one, he explained that he had made it in two pieces because if he had made it in one it would have been too heavy. Now this young man was led to believe by his teacher that he was a mechanical engineer, capable of holding a designing job, and became highly incensed when he was "kidded" by the shop foreman, a practical old fellow in overalls.

Another instance actually occurred. A multi-millionaire, a "captain of industry," purchased a large tract of land for a hunting lodge. To reach this tract of land it was necessary to span a navigable river with a drawbridge. A competent engineer was employed for the purpose of testing, sounding, designing, and erecting this drawbridge, together with certain other buildings and improvements to be made upon the land. When the captain of industry desired to occupy this hunting lodge he discovered that the drinking-water supply was both inadequate and unwholesome. To correct this he proceeded to the local tinshop and had the tinner make an iron cistern or tank. When the job was completed the tank was loaded upon a truck and taken to the hunting lodge via the drawbridge. Upon arriving at the bridge it was found that the tank was too large to pass between the trusses of the superstructure. The captain of industry and the engineer were both very much chagrined; discussion was held of ways and means of getting the tank across the bridge, as no means of water transportation was at hand. It was decided to take the tank back to the tinshop and have it cut apart, and then returned and assembled on the foundation at the hunting lodge. The old Irish bridge tender who had been listening to the conversation asked the captain of industry what he would give him to place the tank safely on the other side of the river. He immediately received the reply, "I will give you $100 if you will do it. Now tell me how you expect to get it over." The old Irish bridge tender proceeded to put a few sacks of sand on the opposite end of the bridge to act as a counterbalance, turned the bridge half-way round, and presto! the tank was on the other side of the river. Now this engineer was capable of designing and erecting a bridge and other permanent improvements, but it took a bridge tender to show him how to get a tank across the river. He was evidently lacking in the small things that make up real engineering ability.

In recent years a certain architectural engineer was called upon to design a warehouse of huge proportions and some four stories high. The particular point at which the building was to be erected had a clay subsoil upon which the footing or the foundation was to rest. This engineer had a series of holes, twelve in number, dug to the desired depth to which he figured the foundation should go; he made the usual soil test by applying load to a 12-in.-square block on soil, and this test showed that the soil failed at different loads ranging from 3600 lb. per sq. ft. to 4400 lb. per sq. ft. Therefore this bright young fellow added together all twelve tests and divided by twelve, declaring that the average was the safe load that the foundation soil would stand. Fortunately the owner of this warehouse had had some engineering experience, so he proceeded to cancel the contract with this young architectural engineer and employed other talent. Now these are the things that pop into the minds of the practical business man when the term "engineer" is used. In other words, the engineer's mistakes are not like the doctor's. One can see the engineer's mistakes after he is through with them, but the doctor's mistakes are buried out of sight.

The idea uppermost in most college graduates' minds in their line of endeavor is that when they receive their diplomas there is nothing else for them to learn, and that for them further thinking or study is unnecessary.

If the colleges would teach their students theory, and make it plain to them that after graduation they themselves would have to work out, in practice, their own salvation, there would be fewer failures in the engineering profession, or for that matter, in any other profession.

The writer does not think that the material the colleges have to work with today is of a poorer quality than it has been in the past. It is true that they have a greater variety and a greater number of men, but he believes the percentage of graduates that are successful in their lines today is greater than it was years ago. This is because of the fact that there are greater opportunities today for college-trained men.

However, the writer does think that the character of the workmen who are handling the material in the colleges today has degenerated in quality. A poor workman may take the finest of materials and yet fail to produce a good article; but a good workman can take poor material and produce a very fair article. Therefore, the solution of the problem lies in having better workmen in the colleges—putting a better finish on the material they have at hand.

L. J. BLACK.[1]

Beaumont, Tex.

Definition of an Engineer

TO THE EDITOR:

The current definition of an engineer adopted by the Institution of Civil Engineers in England, is a man who uses the forces of nature for the benefit of mankind. Such a division is obviously much too broad, as a doctor who gives quinine to a patient obviously also uses forces of nature for the benefit of mankind.

The following might describe an engineer better: "A man who, by means of mechanical constructions, directs natural forces to the benefit of mankind."

This definition would at once exclude such sciences as medicine and biology. It would make the distinction between the chemist and the chemical engineer clear, the former employing reactions and the latter mechanisms.

L. C.

New York, N. Y.

[1] President, Beaumont Iron Works Co. Mem. A.S.M.E.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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Standardization to Prevent Conflagration

TREMENDOUS fire losses aggravated by lack of interchangeability between hose couplings from neighboring cities called in to help have occurred on the average of one to three a year for the last fifty years. The basis for removing this confusion is now provided in the National (American) Standard Fire Hose Coupling Screw Thread. However, there is still much educational work to be done throughout the country to secure its adoption.

The recent approval of this Standard by the American Engineering Standards Committee recalls the history of its development which goes back more than fifty years to the first annual convention of fire chiefs held in Baltimore in 1873, when a committee was appointed to consider the subject and report back. Interest at this time had been aroused on account of the confusion due to misfits experienced in the great Boston fire of 1872. A standard was adopted in 1875, was changed again in 1879, argued over fruitlessly until 1890, and finally brought once more dramatically to public attention by the disastrous conflagration in Baltimore in 1904 when equipment rushed to the aid of the stricken city from New York, Philadelphia, and Washington proved practically useless because of these same misfits in couplings.

The following year the National Fire Protection Association proposed a standard which was adopted by them and the American Water Works Association, and subsequently by the International Association of Fire Engineers (1906) and by The American Society of Mechanical Engineers (1913). In 1921 this national standard was published as a part of the recommendations of the Progress Report of the National Screw Thread Commission. Since that time it has been revised and extended through the joint efforts of the A.S.M.E., the National Board of Fire Underwriters, and the American Water Works Association, and has been approved by the American Engineering Standards Committee. It is now the approved and adopted standard of 17 organizations.

Up to 1921 the standard existed largely as an ideal. Its adoption in 30 per cent of the protected towns and cities of the country has been accomplished by the National Board of Fire Underwriters with the active assistance of state and sectional underwriting organizations. Communities have been educated in the necessity for conforming to the standard campaigns outlined for resizing in zones, and the tools developed by which this can easily be done in the field. With these very effective tools it is now possible to resize and rechase nipples, couplings, hydrant caps, and special fittings, provided that the outside diameters do not vary too greatly above or below the standard, and provided that the original threads are not of too coarse a pitch. It is estimated that only about 10 per cent of the protected communities are unable to standardize their equipment by the use of these tools.

The work of standardization has progressed rapidly since 1919 when the salvaging tools were developed. Of the 7500 protected towns and cities, approximately 2300 now conform to the standard, about 1000 having been originally so and upward of 1300 having been resized by the Board's tools. Important cities in which resizing campaigns have recently been in progress are Boston and Fall River, Mass., Hartford, Conn., Atlantic City, N. J., Baltimore, Md., and Washington, D. C.

The value of the standard is quickly recognized and approval of it is easily obtained, but it is sometimes hard to get the necessary action for the approval and accomplishment of the resizing in a given community. In the meantime the hazard still persists, the extent of which is emphasized by the following list of some of the fires in which lack of interchangeability was a large factor: Salem, Mass., 1914; Paris, Texas, 1916; Augusta, Ga., 1916; Atlanta, Ga., 1917; Thomasville, Ga., 1918; Mobile, Ala., 1919; Worcester, Mass., 1921; Pocomoke City, Md., 1922; Grimes, Ia., 1923. Recently a southern city called upon seven neighboring communities for aid, only to find that six of them were equipped with couplings which would not fit.

The question naturally arises: What can be done?

First: Do not assume that your city has the standard. Make sure for yourself—and make sure that it is the National (American) Standard and not some so-called local standard. If your property is not protected by this standard, see that it is made so. This can be done by creating a favorable public opinion for the adoption of the standard. Write to your local papers, enlist the assistance of the civic organizations of your city, the chamber of commerce, the Rotary and other clubs, and take it up in your own A.S.M.E. Section.

If you meet with apathy or skepticism, plan a demonstration meeting. Borrow a set of resizing tools. Invite the various organizations of your city, the mayor, fire commissioners, the fire chief and marshal. Bring in also the water-works department, their commissioners and engineers, and the fire-insurance representatives in your community. Do not confine the invitations to your own town but get the coöperation of neighboring towns, those who would naturally be called upon in case of trouble. Get samples of their hose couplings and of yours, show how they do not fit, and then, with the special tools, resize the couplings, rechase the threads, and pass the standardized and salvaged parts among the audience. Prove how easily and how satisfactorily this can be done.

But do not stop there. Get the approval, the appropriation, and see that the work is started.

Suppose there are objections. The tools cost money. The mechanics' time costs money. What happens in case of a fire during the salvaging campaign with part standard and part not? These questions are easily answered. The tools can be had for $275, not much of an investment for any community. The work can be done by the regular mechanics of the fire and water-works departments. The plan of accomplishing the resizing without upsetting the routine of the departments and without danger of confusion has been worked out and successfully applied in hundreds of cities. All of this assistance can be got from the National Board of Fire Underwriters.

Success in a given community in a resizing to conform to the National Standard leads to the necessity of carrying out the campaign in all neighboring towns until the entire state has the standard thread. This was easily accomplished in Oregon by the enactment of legislation which established the National Standard as the standard of the state of Oregon and compelled the adoption of it in the purchase of all new equipment and the resizing of existing equipment.

Here is a practical campaign for every Local Section.

JOHN H. HOWLAND.[1]

[1] Engineer, National Board of Fire Underwriters, New York, N. Y.

The Soft-Coal Problem

THE amazing situation facing the soft-coal industry of this country points an instructive moral; and an analysis of the problem, while revealing many interesting features, promises no simple solution. To state the facts, "Too many mines, too many miners"—the surplusage of each being now about 50 per cent—may offer an explanation, but it does not give an answer. The outcome of the situation may be left to run its course with the assurance that economic necessity will eventually force a settlement, but with the facts of the case in mind there ought to be found some solution which will achieve the same result more quickly and with less waste and hardship. The temper of the public has passed the point where it will sit idly by and submit to the hardship, loss, and inconvenience forced on it by uncompromising disputants.

The centers of foment in the situation seem to be demand, wages, and production. For the decrease of expected rate of demand for coal, engineers may be held responsible, for they have urged the principles of efficiency and conservation to a point where the greatest users of coal now do with one pound what formerly they did with two (it has been shown that Class 1 railroads alone in 1924 saved 14,400,000 tons of coal over 1920); they have developed the uses of other fuels such as oil and gas, so that in 5 years—from 1918 to 1923—the ratio of heating value of the coal used to that of oil and gas used has changed from 6 to 1 to 3 to 1; and they have gradually increased the use of hydroelectric power. The rate of prewar growth in the bituminous-coal industry has not been maintained—since 1918 it has declined—in spite of the fact that the rate of demand for energy has been practically constant since 1900, and in the face of an astounding growth in the full-time capacity of the mines.

Engineers are not so directly concerned in the question of wages. Here widely contrasted wage scales in union and non-union fields have added to the unbalance of the economic situation in such a way that whatever profit some union operators have made since the Jacksonville agreement has come from the resale of coal bought from non-union mines, and non-union coal from distant fields has competed on a basis of price with local coal mined under the union wage scale, thus demonstrating the possibility of carrying coals to Newcastle. Under the present conditions of overdevelopment, a downward revision of the union wage scale would result in no permanent relief, as it would be countered by a further reduction in non-union fields. Only as a decreased cost of fuel might result in an increased demand for it would this be in any way effective, and in view of the present ruinously low prices of coal, this is a remote prospect.

Lastly, therefore, is the most important question of all, that of overdevelopment. It is unfortunate that our methods of developing natural resources are so feverish, resulting as they do in alternate seasons of high prices and overproduction, in wasteful methods, in unwarranted investment, and in the establishment of communities of workers whose long periods of misery are never fully compensated by the affluence of good times. The fly-by-night operator who rushes to clamber on the bandwagon of prosperity in the coal industry not only attempts to grab more than his share of today's good, but also robs the future by despoiling the reserves in natural resources. Because coal underlies a farm does not justify its transmutation into "easy money." To the elimination of the uneconomical mine, and to the diversion of surplus miners into other more profitable occupations, the stern law of economic necessity is urging the coal industry.

Although it was made apparent as long ago as 1902, overdevelopment is still the besetting sin of the coal industry. War, strikes, and transportation difficulties have played into the hands of the overexpansionists, but now there seems to be left no artificial stimulus to keep alive this moribund industry. Because long overdue, the period of readjustment may seem unusually severe, but the reorganized industry will demonstrate the necessity of economic production. The hard-fought-for percentages of improvement by which the users of coal have stunted the growth of demand must be duplicated by all producers of coal; and the invariable reliability of service which public utilities have taught the public to expect must, in turn, become a feature of the coal industry.

The existence of the Sherman Anti-Trust Law and the Federal Trade Commission have not simplified the solution of this perplexing problem, for even the most honest and sincere attempts at bettering the situation cannot disregard these factors. The consolidation of mines and the unification of operation, so as to limit the supply when necessary, and improved mining methods by means of electrification of the mines, have been recommended as a solution by the United States Coal Commission. If this is the way of salvation for coal men, how long before they will set their feet therein?

A Protesting Gesture

TO PROTEST against the rates of pay, the engineering employees of Chicago on June 30 took what they intended to be a joint vacation for three days without pay. However, after a half-day, and upon assurance from Mayor Dever that action would be taken, the voluntary vacation was called off.

Engineers as a rule deplore activity by members of the profession which at all resembles a strike, and the tendency is to regard this little exploit of the Chicago engineers in the same manner. It is well, therefore, to scan the facts closely. There are 574 engineers employed by the city of Chicago. Thirty-five have left the city since January 1 and turnover costs are estimated as about $1000 per man. The rates paid for engineering work by the city do not compare favorably with rates paid for the same work by railroads and private engineering firms. As this condition was known to engineering officials and they and the mayor were sympathetic, this protesting feature to bring the matters forcefully to the attention of the finance committee of the city council seemed necessary. It is also well to note that the movement had the support of the engineering-department heads, and that the men on emergency work and important projects did not forsake their tasks.

Apprenticeship

MR. FALK'S paper advocating a national plan of apprenticeship was presented at the Milwaukee Spring Meeting of the A.S.M.E. and elicited a large amount of exceedingly interesting discussion which is reported in brief in this issue of MECHANICAL Engineering. Mr. Falk's paper also attracted the attention of *The Engineer*, of London, which points out that the problem of vocational training is a vital one for British industries. The editorial, however, does come to the defense of old-fashioned apprenticeship, and when we consider that the early pioneers in mechanical engineering development, such as Maudsley, Whitworth and a Nasmyth, were the products of apprenticeship, the views of the English editorial writer are of exceeding interest to us.

Taking it all in all, apprenticeship bred as fine engineers, both civil and mechanical, as the world is likely ever to see. It had its defects, it had its black sheep but, on the whole, the results were very satisfactory. From an early age, too early even in recent years to accord with modern views, the young engineer was started upon a vocational course of education of a very practical kind. He did not find himself at the age of one and twenty—as he may today—equipped—bless the mark!—to open his career in a dozen different directions, and uncertain which to take. When he came of age he was out of his time, and a full graduate of the trade or profession to which he had been indentured. He had had to rough it; he had had to scramble for knowledge; he had had to pick up his own experience by failure; he had had to depend upon his own powers of observation and exercise his own tact in extracting secret of his craft from their owners. It was a hardish life, but it winnowed out the good from the bad, the men of character from those without, the men of aptitude from those lacking it. Who knows how much America herself owes to the mechanics who were trained by the roughest methods in the "two-man" shops and forges of her little knots of settlers? It was in such places that the mechanical instinct was in nurtured. Westinghouse was the product of such a shop, and we know not how many more of the men who have made the American mechanical engineer famous the world over for his ingenuity. In this country one might with more ease number a score of great engineers who had been made by the old method than a dozen who had been made by the new. But the conditions of those days have gone, and it is fruitless to lament them. Rather must we, too,

consider as our cousins are doing if we can save something of the merits of the old system and combine it with the new. Fortunately, being conservative by instinct, we still hold to apprenticeship in some measure, and some of our great works have apprenticeship schemes conducted on modernized lines.

The greatest of all the virtues of the old, rough method were its qualities as a character builder. No other system yet discovered is so good in that respect. That is their weakness. Only the A-1 men won through the hard fight of our forbears. We have made things so easy that the man of C-3 character and physique is not infrequently able to block the path of the better-fitted man, although through his own disabilities he cannot himself reach the summit. We still pay far more attention to success in examinations than to those things which really count in the battle of life. It is our proud, democratic boast that we give all an equal chance, that we have set up "a ladder from the board school to the university and the promised land beyond." But the ladder tends to become an escalator on to which the candidate need do no more than step to be carried to the top. It has not yet been proved that we are doing the best for our industries by this method. In the old system men had to fight for and seize their opportunities, now they are presented with them. We gain something, no doubt, by this method. There is greater equality and greater volume of knowledge. That is something; but, on the other hand, there is less outstanding capacity. There are more able men in engineering, far more, than there ever were; but there are fewer great men. Is that the result of the new system of training and education, or the inevitable result of the changed conditions in the industries?

The Status of the Engineer

UNDER this heading London *Engineering* prints a very interesting editorial commenting on the report of the International Labor Office on the status of technicians in different countries. Some of the paragraphs of the English editorial supplement the editorial by Dean Kimball on the report in the June issue of MECHANICAL ENGINEERING and should be read in conjunction with that statement. They are printed below:

Engineering has not yet been reduced to a science, and if past experience holds good it is never likely to be. Some branches of the profession must always partake much more of the nature of an art than of a science, as was strikingly exemplified during the American war of Secession when an experienced contractor replaced a railway bridge before the professional corps of engineers had thought out their preliminary plans. In fact, what a maintenance engineer needs is experience and not very much else. Again, when new industries are established certain men grow up with them, and have often to "skirmish ahead of the army" of science. This was notably the case in water-works engineering and the conditions were repeated when the heavy electrical industries were founded. The late C. E. L. Brown, for example, had no academic qualifications, but this did not prevent him from being one of the founders of modern methods of electric power distribution.

By a law recently passed in Italy, a man with similar qualification will not in future be allowed to describe himself as an engineer, and there has been similar legislation in Hungary. The Austrian laws also prescribe drastic penalties for the irregular assumption of the title of engineer. It is very improbable that any similar course will be taken here or in America. In both countries the standing of an engineer is largely gaged by his membership of certain technical societies, which are careful to accord full membership only to fully qualified men, though they are indifferent as to how these qualifications may have been gained. In France, too, the opposition to proposals for restricting the title to graduates comes mainly from the engineers themselves, and in fact, speaking generally, it would seem that the movement in favor of such a course is strongest in countries which are the least industrially developed. In certain other countries in which the restrictions are less stringent than in Italy or Hungary, there are regulations providing that certain technical officials must be graduates from recognized engineering schools. This holds good in Germany and also in Spain, and the same policy has been adopted in certain of the republics of Latin America.

H. Foster Bain Appointed Secretary of the A.I.M.E.

F. F. SHARPLESS having tendered his resignation as secretary of the Institute of Mining and Metallurgical Engineers, after having served in that capacity for four years, the board of directors at its meeting on June 26 elected Dr. H. Foster Bain, at present director of the Bureau of Mines, to the position. Mr. Sharpless becomes secretary emeritus and will remain at headquarters, giving a portion of his time to institute affairs until the new management is operating smoothly. Dr. Bain took active charge as secretary of the institute and editor of its publications on the first of July.

Dr. Bain is well known to the entire engineering profession, having served as Director of the United States Bureau of Mines since 1921. He is a graduate of Moores Hill College of Indiana and spent two years in graduate work at Johns Hopkins and later received the degree of Ph. D. from the University of Chicago. His early experience was obtained as assistant state geologist of Iowa and as consulting engineer and mine operator. He served as geologist for the United States Geological Survey and as director of the Illinois Geological Survey. From 1909 to 1914 he was the editor of *Mining and Scientific Press*, leaving that position to become editor of the *Mining Magazine* of London, for two years. He was engaged in foreign exploration in South Africa and the Far East for four years, with the exception of one year when he served as assistant secretary of the United States Bureau of Mines in charge of war materials. He is the author of numerous government and state reports and short articles in literary and technical magazines.

H. FOSTER BAIN

New Haven Machine-Tool Exhibition

THE important feature of the New Haven Machine Tool Exhibition will be the technical program which is now being arranged by the Machine Shop Practice Division of the A.S.M.E. The Exhibition will be held from September 8 through 11, 1925, in the Mason Laboratory of Yale University. The sessions will be held in Dunham Laboratory directly across the street from Mason Laboratory, starting Wednesday afternoon, September 9.

The feature address of the meeting will be given on Wednesday evening by O. B. Iles, president of the National Machine Tool Builders' Association, and will deal with the future of the machine-tool industry. The other speakers of the evening will be W. H. Rastall, chief of the Industrial Machinery Division of the Department of Commerce, on the foreign trade outlook in the machine-tool field and William B. Stout, president of the Stout Metal Airplane Company, who will present a paper on all-metal airplanes.

On Friday afternoon, there will be a session on shop training methods, the program for which is being arranged by Prof. John T. Faig, president of Ohio Mechanics' Institute and chairman of the A.S.M.E. Committee on Education and Training for the Industries.

The technical sessions which will be held on Wednesday and Thursday afternoons will deal with centerless grinding, cylindrical lapping, high-speed cutting of brass, and safety in the machine shop. The advance papers for the sessions will appear in the September issue of MECHANICAL ENGINEERING.

The feature on Thursday evening will be the dinner and round-table discussion, at which the topics to be taken up will include inspection methods and precision measurements, power-press work, production milling, and shop training methods.

In the conduct of the exhibition, the New Haven Section of the Society is receiving the active coöperation of the New Haven Chamber of Commerce and the Mechanical Engineering Department of the Sheffield Scientific School of Yale University. The interest that has developed in this exhibition over the five years of its growth and the excellent list of prospective exhibitors assure the success of the coming event.

The Portland Regional Meeting

AS HAD been predicted, the Regional Meeting at Portland, Oregon, June 22–25, began and was carried through most successfully. An excellent technical program, witha series of interesting excursions of novel and scenic interest, attracted a goodly number. Over two hundred registered at Society headquarters in the Portland Hotel.

The convention was opened on Monday morning, with brief addresses of welcome by William C. Shaw, chairman of the Portland Local Section, and Franklin T. Griffith, of the Portland Electric Power Co., president of the National Electric Light Association. Technical sessions followed. An account of the discussion at the meeting will be given in the September issue of MECHANICAL ENGINEERING.

Monday evening was devoted to a banquet, which was attended by about one hundred, of whom one-third were ladies.

On Tuesday morning a large party went by special train to visit the Oak Grove hydroelectric plant of the Portland Electric Power Co., while another group visited the hog-fuel power plant of the Northwestern Electric Co. in Portland. In the afternoon many motored to the factory of the Crown Willamette Paper Co. at West Linn, where they saw the manufacture of newsprint by modern machinery which turns it out at the rate of a thousand feet a minute.

Two all-day excursions occupied the third day of the meeting. One group, as guests of the Long-Bell Lumber Co., left by the steamer *Georgiana* for Longview, Wash., where they saw the latest methods of lumbering as well as the logging operations at Ryderwood.

The second group on Wednesday was entertained by the Port of Portland Commission. Leaving on the steamer *Portland*, the engineers (and ladies) visited the new electric dredge *Clackamas*, which was operated that day for the first time. Only two of its large Diesel engines were running, but the results were most interesting. The *Tualatin* and the *Columbia*, steam-turbine dredges operated by the Port, also were inspected. During and after luncheon, which was served on board the steamer, the visitors were given a view of the lower river and harbor facilities, especially the wing dams used for deepening the main channel of the river and Municipal Terminal No. 4.

Fortunately, the Mount Hood Loop trip had been scheduled for the last day of the meeting. Leaving in motor cars at half-past eight in the morning, the visitors were taken first to the Government camp, then up the Loop Road, to luncheon at a mountain inn and around the mountain, so that the return through the Hood River valley and along the Columbia River Highway was made in the cooler part of the day and after sundown.

The committee in charge of arrangements for the Portland meeting included W. C. Shaw and A. H. T. Williams, respectively, chairman and secretary of the Local Section, E. W. Lazell, A. C. Sullivan, Charles W. Bale, G. F. McDougall, and H. S. Bastian.

The Bell System Educational Conference

REPORTS of the Bell System Educational Conference indicate that it was a success. This unique venture in vocational guidance was designed to teach deans and professors of engineering that the various branches of the telephone industry have a majority of problems for the solution of which the services of mechanical engineers must be engaged. The very convincing method of actual demonstration under ideal conditions was applied.

Briefly, about 75 heads of mechanical engineering departments and deans of engineering schools assembled in Chicago, June 22 to 27, by personal invitation of the Bell System, and participated in a conference with about 85 officers, personnel, and other representatives of the system. The professional features of the program consisted in an extensive study and explanation of manual and machine switching, followed by tours of the Hawthorne works of the Western Electric Company and addresses on appropriate subjects by experts. The manner in which these features of the conference were conceived and executed command the highest praise.

An important lesson was impressively taught: Teachers who may not and often cannot get back into the industries obtained a clearer and broader conception of modern engineering by first-hand inspection and intelligent exposition. They learned that an industry nominally electrical has a greater need for mechanical engineers than is satisfied by the supply. In addition, in thus being thrown together this selected group of men having varied interests in a common problem were given leisure and opportunity for an interchange of views and opinions. Teachers who train men for the industries came in contact with personnel managers who hire engineering graduates.

Statistics gathered by the Board of Investigation and Coördination of the Society for the Promotion of Engineering Education show that there is a deplorable ignorance of the field of engineering on the part of those electing to attend engineering colleges, resulting in excessive eliminations between matriculation and graduation and indicating the need for intelligent guidance for preparatory students. Statistics further show that less than one-quarter of the jobs obtained by recent graduates have been obtained through the schools or members of faculties, and that there is much shifting about of engineering graduates during the first few years after graduation, showing an apparent lack of interest in, and responsibility toward, men recently thrust into the industrial world. Such conferences as this of the Bell System will do much toward educating the educators, keeping them abreast of developments and opportunities, and furthering the progress of vocational guidance. It is to be hoped that more of our great industrial organizations will assist by calling similar conferences.

Industrial Engineering to be Taught at Lehigh

THE announcement by Lehigh University of the inauguration of a new course, to be known as Industrial Engineering, the purpose of which is to equip engineers who enter industry with a sound understanding of the fundamentals of finance, accounting, and business, adds another to the long list of the well-known technical schools and colleges of engineering that have followed this significant trend in educational development.

The fundamental technical aspects of all production businesses are so closely allied to engineering that a modern executive will find, probably, no better training for his work than in such courses as the one announced by Lehigh University. A glance at the curriculum shows that it is established on a conservative basis, with a liberal allowance of engineering. It is gratifying to note that the first two years are identical with those of the mechanical and electrical engineering courses, and that during the third and fourth years there is an even distribution between professional and business subjects. The courses in business, to judge from their names, are not only of fundamental character but are those most susceptible of scientific treatment. The inclusion in the senior year of a "free elective" is an indication of enlightened liberalism in engineering education.

The fads in engineering education have run the gamut of mechanics, materials, motive power, management, and men, and now enter the arena of money. From each phase has been saved the best. The works of engineers have broadened the field of their usefulness and have made it necessary for most executives to know something of the elements of engineering. Whether we say that executives have usurped the financial benefits of engineering progress at the expense of the engineers, or that engineers have usurped the positions of executives, thus reaping those financial benefits in some measure for themselves, makes little difference. Statistics show a decided tendency for graduates of engineering colleges to develop into executives. The lack of the training that Lehigh now offers has been the criticism in the past of the curricula of engineering schools.

So it is that the invariable ambition of every boy to become this country's president finds outlet at college age in a desire to be president of a great business enterprise, and to the satisfaction of this desire our colleges are turning their attention. The divorcement of the business, administrative or industrial, from the purely professional courses is wiser than the submergence of the less popular professional into the financially more attractive courses, as it makes possible more rigorous and scientific development of engineering by those mentally and temperamentally equipped to carry it on. Even a nation of business executives has need of science and of engineers. Engineering has a multitude of Babbitts; may it never lack its necessary leaven of Arrowsmiths.

Saratoga Meeting of the A.I.E.E.

Papers and Reports of Interest to Mechanical Engineers—Report of Committee on Power Generation

THE confession by the Committee on Power Generation of the A.I.E.E. that its report, delivered at the annual convention, Saratoga Springs, N. Y., June 22 to 26, "falls more specifically within the scope of The American Society of Mechanical Engineers than of the Institute" justifies a somewhat extended review of it. A bibliography of more than 300 items is a valuable part of the report.

After commenting on the bewildering rate of progress as demonstrated by the actual generation of power in an 80,000-kw. station at a coal rate per kw-hr. 20 per cent lower than any previous performance on a commercial scale, the report lists the following important technical achievements of the last year.

1 The operation of two 40,000-kw. G. E. single-cylinder turbines in the Philo station of the Ohio Power Co. with a water rate corresponding to the 40,000-kw. load and with no steam bled for feedwater heating of approximately 8 lb. per kw-hr. The turbines operate on a reheat cycle, throttle pressure 550 lb. per sq. in. gage, temperature 725 deg. fahr., reheating at 155 lb. gage to 725 deg. fahr., and exhaust at 0.5 lb. per sq. in. absolute. Normally steam will be bled from two stages, for feed heating. Economizers and air preheaters are used. The heat consumption has over a week's time been as low as 13,715 B.t.u. per kw-hr. of net station send-out, this performance corresponding to a load factor of 81 per cent for the week.

2 The initial operation of the Crawford Ave. Station of the Commonwealth Edison Co., Chicago, in which are installed three cross-compound turbine units by different manufacturers: a 50,000-kw. Parsons, a 60,000-kw. General Electric, and a 50,000-kw. Westinghouse.

3 The construction by the General Electric Co. of a 3000-kw. turbine, running at 3600 r.p.m., taking steam at 1200 lb. per sq. in. gage, 700 deg. fahr., and exhausting at 350 lb., at which pressure the steam will be reheated to 700 deg. fahr. and discharged into the main header of the station. This turbine will be located in the Weymouth station of the Edison Electric Illuminating Co. of Boston.

4 The extreme development of the regenerative cycle in the operation of two 35,000-kw. Westinghouse turbines in the Colf. x station of the Duquesne Light Co., Pittsburgh, with four stages of bleeding to raise the feedwater to 350 deg. fahr.

5 The attainment of on test of an efficiency of 92.9 per cent at 140 per cent of rating, 89.8 per cent at 270 per cent of rating, and an average gross efficiency for a month's time of 90.4 per cent by four double-ended Stirling boilers at the Lake Shore station of the Cleveland Electric Illuminating Co. The boilers contain 30,600 sq. ft. of heating surface and 22,469 sq. ft. of economizer surface. They are equipped with pulverized-coal furnaces and use coal with 11 per cent ash, 3.5 per cent sulphur, heating value of 12,600 B.t.u. per lb. and a fusing point of ash of 2150 deg. The unburned-fuel loss is a fraction of one per cent and the flue gases are reduced to 250 to 230 deg. fahr.

6 The attainment at the Cahokia station of the Union Electric Light and Power Co., St. Louis, with a very low grade of coal, pulverized, and without the use of economizers or air heaters, of an average gross boiler-room efficiency as high as 81.2 per cent over a month's time.

7 The successful operation in the Chester station of the Philadelphia Electric Co. of underfeed stokers operated at times at 300 per cent of rating with air delivered to the stoker windbox at a temperature of 550 deg. fahr. While the fuel bed was free from large clinkers and easy to maintain, and stoker maintenance not greatly increased, furnace walls of conventional design will not withstand the high furnace temperatures obtained with the use of preheated air.

8 Further development of water-cooled furnace side walls.

9 The removal at the Trenton Channel station of the Detroit Edison Co. of 75 per cent of solids in suspension in flue gas by Cottrell precipitators.

10 The successful operation of a 70-in. Fuller air-separating type of pulverizing mill at Cahokia, pulzerizing 28 net tons of Illinois coal per hour with a combined power consumption of 294 kw. The mill and driving motor occupy a floor space of 13 by 21 ft.

11 The development by the Fuller-Lehigh Co., of a "well type" furnace, 8 ft. square by 8 ft. high, in which 32,700 lb. of coal per hour have been completely burned.

12 The successful operation in several stations of automatic combustion-control equipment.

13 The efficient operation of large single-pass condensers with less than 1 sq. ft. of surface installed per kw. of turbine capacity, in the Waterside station of the New York Edison Co., and the Trenton Channel station of the Detroit Edison Co.

14 The placing in operation of five 30,000-kw. and nine 20,000-kw. turbines of the new Westinghouse multi-exhaust Baumann type.

15 The construction by the General Electric Co. of two 50,000-kw., 62,500-kva., 1800-r.p.m. tandem-compound turbo-generators for the new station of the Philadelphia Electric Co., and two 60,000-kw., 60,000-kwa., 1500-r.p.m. single-cylinder turbo-generators for the 14th Street Station of the New York Edison Co.

16 The use of three new methods of securing reliability of the power supply for auxiliaries in large steam stations:

a Coupling the generator for supplying power to essential auxiliaries directly to the main generator driven by the main turbine.

b The use of separate turbo-generators operating condensing and constituting a separate power plant within the larger power plant.

c The use of a transformer tied directly to the leads of the main turbine.

17 The extensive use of waste heat and steam driers for removing moisture from coal before it is pulverized.

Pausing to look back over a period of about eight years, the report makes note of some important developments, and plots the downward tendency of heat consumption with the years, showing the acceleration which the high prices of coal have imparted to this tendency and the retarding effect of the war. The estimate of future trend is also plotted, and the heat-consumption possibilities of the mercury-vapor plant recently installed at Hartford. The possibilities of future developments which will result in higher operating efficiencies are grouped as follows:

a The further development of commercial equipment for use in the application of the mercury-vapor-steam cycle.

b The development of superheaters, high-pressure steam piping, values and turbines for operation in connection with steam temperatures of 800 deg. fahr. or higher.

c The use of hydrogen or some equally suitable gas as the cooling medium in connection with closed ventilating systems for turbo-generators, and the development of new generator designs which will take advantage of all the possibilities of the new cooling medium.

Turning from technical achievements and the reduction in heat consumption, the report analyzes the trend of the factors involved in the total cost of power, plotting operating labor and superintendence, maintenance, fuel cost, and fixed charges on the investment. While the first two have shown practically no variation during the past eight years, fuel cost and fixed charges have had decided variations. While there has been a reduction in fuel costs in large stations due to improvements and the declining price of coal, fixed charges have a definite upward tendency. Says the report:

> The indications are that if we strive for lower fuel costs by the use of more efficient stations, the fixed charges per kw-hr. will rise still higher, and the increase in fixed charges per kw-hr. will more than offset the decrease in fuel cost per kw-hr. The real job which the power-station engineer has ahead of him is to decrease the fixed charges per kw-hr. and to re-establish the proper balance between fuel costs and fixed charges."

Tendencies in the design of steam generating stations are classified by the report as follows:

1 Tendencies which improve the reliability of the power station, increase its cost, but do not appreciably affect the operating efficiency; for example:

a The use of house turbines, auxiliary generators and storage batteries for insuring the auxiliary power supply.

b Isolated-phase layout and the use of reactors and other protective devices in the switchhouse.

c The duplication of auxiliaries, and provision of excessive amounts of spare capacity in boilers and turbines.

2 Tendencies which decrease the coal consumption per kw-hr. and increase the cost of the power station; for example:

a The use of excessively high steam pressures taken together with a single stage of steam reheating during its expansion.

b The use of pulverized-fuel-burning equipment.

c The use of adjustable-speed motors for driving auxiliaries where saving in power consumption at light loads is the consideration.

d The use of air heaters or economizers usually falls in this classification.

e The use of an excessively large amount of surface in the surface condensers for the main turbines.

3 Tendencies which decrease the coal consumption per kw-hr. and also result in a reduction in the cost of the power station and perhaps in the cost of operating labor; for example:

a The use of electrically driven auxiliaries.

b The use of moderately high steam pressures without reheating.

c The use of the highest steam temperatures which are possible with existing materials.

d The use of large turbines and large boilers.

e The use of three- or four-stage bleeding for raising the temperature of feedwater to within 75 deg. or 100 deg. of saturated-steam temperature.

f The use of large mills for pulverizing coal.

4 Tendencies which add to the cost of the station without improving either its reliability or appreciably decreasing its coal consumption; for example:

a Insufficient care given to grouping of equipment and waste space in power-station building.
b Too many architectural frills.

While noting no such revolutionary changes in the field of hydroelectric power as in steam power, the report points to the definite tendency toward the use of larger water-wheel turbines and larger water-wheel generators, the object being not higher efficiency but lower cost per unit of installed capacity. The factors limiting size are summarized by W. M. White as (*a*) shipping facilities, (*b*) material size limits, (*c*) economical generator speeds, (*d*) manufacturing limits, and (*e*) strength and life of parts.

The trend of modern practice seems to be toward automatic generating stations, although there is a feeling that the complete automatic hydroelectric station is limited to the smaller sizes. A noticeable tendency in connection with hydroelectric plants in the West has been the trend toward more permanent construction. There is also a tendency to get away from direct-connected exciters on the main generator shaft, making the main generator easier to dismantle and reassemble. The three principal causes of pitting of turbine runners are believed to be excessive draft head, excessive specific speed, and poor design, although there is considerable difference of opinion as to their relative importance. A considerable amount of experimental work has been done on draft tubes but there does not seem to be any general agreement as to which type is the most satisfactory, those which apparently give the highest efficiency usually being very much more expensive to build.

INDUSTRIAL APPLICATIONS OF ELECTRICITY

The report of the committee on general power appliances presents a condensed summary of general progress in power applications as recorded in engineering publications during the past year, and contains a bibliography of more than one hundred items. Progress is being steadily made along the line of more efficient power drives and control equipment and drive arrangements better suited to the changing operating conditions or tending toward lower maintenance with improved operation from the standpoint of production in manufacturing operations. Outstanding points in this connection are improved motor constuction, modifications in motor applications to speed up production, new types of control, improved resistors, new forms of limit stops and safety features in control applications: installation of automatic equipment in steel-mill substations, extended use of electric heating, and the like.

The committee on applications to iron and steel production reported that while the steam turbine still continued to hold first place as a prime mover in the steel plant, it was an open question whether the greater economies which are being sought throughout the industry and improvements in engine and cleaners might not bring the slow-speed gas engine back into favor. To even a greater extent than usual, this year has been marked by a replacement of existing engine drives by modern electrical equipment. An interesting tendency in auxiliary mill-motor control is toward the use of time limit acceleration instead of current limit. With the expiration of patents covering certain alloys of value in resistor units the development of annealing and heat-treating furnaces has received marked impetus. The use of arc welding for repair of broken parts has increased. Investigation of the two-voltage system of operation of "arc furnaces," a high voltage for melting followed by a low voltage for refining, indicates that there is no deleterious effect on the product, while there is a decided saving in power and electrode consumption.

During the year there has been no outstanding and novel development of the use of electricity in the mining industry, reports the committee on applications to mining work, but a steady growth of application. Reliable records show savings as high as 25 cents per ton resulting from change-over from steam to electricity, and the standby losses of electrified mines are less serious.

The committee on communication summarized thirteen papers on communication which had been presented to the institute under its auspices.

The notable advances in lighting were reported by the committee on production and application of light as better and more intensive application of available equipment and methods rather than of fundamental methods. The outstanding event of the year was a nation-wide campaign of education on home lighting conducted during the fall of 1924 and representing the most extensive coöperative movement ever undertaken by the electrical industry.

In commenting on developments in electrical machine design, the committee on electrical machinery opened its report as follows:

> The past year has shown a marked advancement in the art of electrical machinery, not only in the successful starting and operation of machines larger than any ever built up to this time, but also in the purchase and partial completion of machines still greater in size. Accompanying the trend toward larger sizes of units, there has been much investigation along the lines of ventilation, insulation, mechanical strength of materials, losses in iron and copper, the effect of expansion and contraction on the insulation of long armature coils balance of the moving parts, and the dissipation of heat from flat surfaces.
>
> New applications of electrical machinery have been made in various industrial lines and transportation. The design of an electric locomotive having d.c. motors and operating from a.c. feeders was adopted. Diesel-electric drives have been applied to locomotives in sizes heretofore not attempted for this type of drive.

The committee on research comments as follows:

> A general review of the work in electrical-engineering research during the past year reveals two striking facts. First, the great amount of experimental research under way and the wide range of problem; and, second, the lack of coördination among various workers in the same or allied fields. Obviously, a function of the Committee on Research should be the bringing about of such coördination if in any way possible. The difficulty here is in obtaining information as to the work undertaken in widely separated localities. Often the Committee's first knowledge of a piece of work is the appearance of the paper presenting the results. This state of affairs must continue so long as the original conception of the problem arises in the interest of some individual, in a university laboratory, or in the special needs of some manufacturing process.

PAPERS ON HYDROELECTRIC DEVELOPMENT

Two papers on hydroelectric power development—Power Possibilities at Muscle Shoals, Alabama, by Samuel S. Wyer, Consulting Engineer, Columbus, Ohio, Mem. A.S.M.E., and Hydroelectric Development of the Saguenay River, by W. S. Lee, Southern Power Co., Charlotte, N. C., Mem. A.S.M.E.—are also of interest to mechanical engineers.

The paper on Muscle Shoals is a report of a study made in February and March, 1925, the author having access to the records of the War Department. The object of the report is to present the basic facts pertaining to the whole Muscle Shoals situation in such a way that the layman may make his own evaluation of what has and what can be done at Muscle Shoals. By "Muscle Shoals" is meant the water-power development now nearing completion at Wilson Dam. Many popular misconceptions are clarified. The present and future available power at Muscle Shoals is compared with that at Niagara and in the rest of the United States. With regard to what to do with Muscle Shoals, the author says:

> Within easy transmitting distance from Muscle Shoals there is an adequate, existing, electric-power market that can promptly absorb all of the electric power that can be developed. This market can be economically reached and effectively served only as Muscle Shoals is made part of an integrated, interconnected transmission system, so that advantageously located steam plants and storage reservoirs can be used for supplementing the otherwise practically valueless secondary power at Muscle Shoals.

The water-power development at Isle Maligne, on the Saguenay River, Province of Quebec, Canada, is the largest single installation ever undertaken. A total power-house installation of 540,000 hp. is being made, of which 360,000 hp. is completely and 180,000 hp. partially installed. The building of a station in a remote section with extreme difficulties due to weather and floods called for very careful planning and coördination of the various parts of the work. The steps in the construction of the plant are described at length to bring out the value and importance of designing with the idea of coördination and coöperation with the construction forces. The design and layout of the construction plant were given as much attention as the design of the power house, resulting in a great amount of work being executed in a comparatively short time.

The Saguenay River, a tributary of the St. Lawrence, flows out of Lake St. John, about 100 miles north of Quebec, by two channels, the smaller of which is practically dry in winter. The power company is permitted to utilize the storage capacity of the lake between ordinary low and high water, a depth of about 17.5 ft. and a capacity of about 187.1 trillion cu. ft. Isle Maligne is about 1¼ miles long and divides the larger of the two outlets into two rocky gorges two miles above the juncture of the outlets and at a point where the

mean low-water level of the river is 105 ft. below that of the lake and 122.5 ft. below the level of the fully unpounded lake. The layout permits the drawing of the water into turbines directly from the natural storage of the lake from an average of about 20 ft. below its surface so that no trouble is anticipated from ice.

After a description of the construction features of the dams and spillways necessary and of the equipment and methods used, the power house is described.

Considering the 720-ft. length of the power house and the 163.5-ft. width of the power-house bulkhead and substructure, it was deemed necessary to provide for expansion and contraction of the structure due to temperature changes. The intake to each of the 12 turbine flumes consists of two 16 by 22-ft. openings formed in concrete masonry. Each opening contains a rectangular gate of the butterfly-valve type operated by an individual, completely enclosed hoist located at the top of the power-house bulkhead, and controlled by push button on top of the bulkhead and from the power-house bench board for distant closing in emergency. The two flumes converge into a 22-ft.-diameter opening connected to the turbine spiral casing. The draft tubes are of the White hydraucone design. When all twelve turbines are operating at full load under an effective head of 110 ft., the total discharge into the tail race is estimated at 50,400 cu. ft. per sec. The width of the tail race immediately below the downstream face of the power house is 657.5 ft., the depth below normal water surface is 23 ft., and the total length to the point where it joins the river, 800 ft.

The power-house installation consists of 12 vertical single-runner Francis turbines operating at 112.5 r.p.m. Eight are now installed. At 110 ft. head the horsepower of each turbine at best efficiency is 40,000. The maximum at this head is 45,000, and at 120 ft. head the maximum capacity is 50,000 hp. The eight generators now completely installed have a continuous full-load rating of 30,000 kva. or 24,000 kw. at 80 per cent power factor, and are 13,200-volt, three-phase, 60-cycle machines.

The paper ends with a description of methods employed in construction of the power house, spillways, and earth dams.

The A.S.T.M. Annual Meeting

Iron and Steel Specifications, Corrosion, Research Activities and Non-Ferrous Metals Reports

THE 28th annual meeting of the American Society for Testing Materials, held at Atlantic City from June 23 to 26, revealed the increasing scope of the society's activities and the variety of materials which come under its scrutiny. Some of the reports and papers dealing with road materials, waterproofing and roofing materials, concrete, cement, lime and gypsum are of greater interest to civil than to mechanical engineers, and others, such as paints, textiles, insulating materials, ceramics, rubber, and slate may not have as broad an appeal as those relating to the metals, corrosion, and coal, but when to this list are added such subjects as research, fatigue testing of metals, materials used at high pressures for superheated steam, and the purchasing of materials on specification, the truth of the statement in the presidential address by F. M. Farmer that the society serves all industry is at once apparent.

The memories of the first president and first secretary of the society were honored at this meeting by the establishment of the Dudley Medal, to be awarded each year for the best paper advancing the knowledge of materials, and the Marburg Lecture, to be delivered annually by an outstanding authority in some field of material research. The recent death of Mansfield Merriman, one of the founders and an early president of the society, was officially noted in resolutions commemorating his services to engineering.

The newly elected president of the society, Walter H. Fulweiler, chemical engineer of the United Gas Improvement Co., was the recipient in 1908 of the Beale medal of the American Gas Institute, and in 1922 of the Grasselli medal of the Society of Chemical Industry. The new vice-president is Prof. H. F. Moore, of the University of Illinois, whose investigations under the direction of the International Research Council on the fatigue of metals have gained for him an international reputation.

Reports and Papers

Tentative revisions of the specifications for wrought iron for pipe, staybolts, extra refined bars, and engine bolts were submitted by committee A-2, and the inauguration of a program of research in wrought iron was announced.

The acceptance as tentative of a revised arbitration bar for cast iron, 1.2 in. in diameter and tested on 18-in. supports, standard in Germany and one of three standards now in use in England, was recommended by committee A-3.

In the report of committee A-7 on malleable castings it was proposed to add to the present specifications the requirement that test pieces shall show a minimum yield point of 30,000 lb. per sq. in. in order that engineers may intelligently select a unit stress for calculations.

Committee A-1 on steel presented tentative specifications for structural silicon steel, for carbon-steel castings for valves, flanges, and fittings for high-temperature service, and for alloy-steel bolting material for use at high temperatures.

Committee A-4 on heat treatment of iron and steel recommended a new practice for carburizing and for heat treatment of carburized objects to replace the present practice.

Methods for sampling ferroalloys and specifications for ferrosilicon, ferrovanadium, ferrochrome, spiegeleisen, ferromanganese, and tungsten powder were presented by committee A-9 on ferroalloys.

Paul L. Irwin, of the Westinghouse Electric and Manufacturing Co., described an improved fatigue-testing machine in a paper entitled Fatigue of Metals by Direct Stress, and R. R. Moore, chief of physical testing branch, McCook Field, Dayton, Ohio, reported on Some Fatigue Tests on Non-Ferrous Metals, including pure aluminum and magnesium, a forged magnesium-aluminum alloy, and naval brass. T. D. Lynch, N. L. Mochel, and P. J. McVetty, all of the Westinghouse Electric and Manufacturing Co., presented a paper on Tensile Properties of Metals at High Temperature Showing Effect of Stress and Time, and Prof. T. McL. Jasper, of the University of Illinois, reported Some Typical Static and Fatigue Tests on Steel at Elevated Temperatures.

Important work on the investigation of problems of corrosion was reported by committee A-5 on corrosion of iron and steel, outlining an extensive investigation on field exposure tests and accelerated corrosion tests on metal-coated articles, giving details of tests of zinc-coated sheets, wire, woven and link-chain field fencing, structural shapes, hardware, etc., and submitting a revision of the tentative, specifications for hot-dipped galvanized sheets and a preliminary draft of requirements for galvanized wire. Committee B-3 reported progress on testing of methods for total immersion, alternate immersion, spray, and accelerated electrolytic corrosion tests of nickel, zinc, lead, copper, aluminum, and Admiralty metal. Two papers on corrosion were also read, Accelerated Corrosion Tests of Bare Overhead Electrical Conductors, by Frank F. Fowle, consulting engineer, Chicago, and Evolution of Corrosion Tests, by E. Blough, technical director, Aluminum Co. of America, Pittsburgh.

There were three committee reports and two papers on the non-ferrous metals. Committee B-1 on copper wire presented a revision of tentative specifications for hard-drawn copper trolley wire, and proposed new tentative specifications for high-strength bronze trolley wire. New tentative specifications for Muntz metal condenser-tube plates were presented by the committee on non-ferrous metals and alloys. This report also submitted revisions of standard specifications for copper-wire bars, for Admiralty condenser tubes and for light aluminum-casting alloys, and presented a statement of the antimony situation. Committee D-4 reported on exposure tests of wire-screen cloth. Norman B. Pilling, of the International Nickel Co., Bayonne, N. J., and George P. Hallowell, of the Westinghouse Electric and Manufacturing Co., Pittsburgh, presented a paper on Softening of Hard-Rolled Electrolytic Copper, and E. H.

Dix, Jr., metallurgist, research bureau, Aluminum Co. of America, New Kensington, Pa., dealt with a metallographic study of the occurrence of iron in aluminum alloys in a Note on the Microstructure of Aluminum-Iron Alloys.

Committee E-4 on metallography submitted a tentative recommended practice for thermal analysis of steel, and a special subcommittee reviewed the subject of X-ray metallography and X-ray crystallography. H. S. Rowden, Bureau of Standards, Washington, presented a report on micro-hardness as determined by the scratch-hardness method.

Outside the field of metals only relatively few of the reports and papers are of primary interest to mechanical engineers in general. Of these there is the report of the committee C-8 on refractories, including a report of an industrial survey committee on uses of refractories in the malleable-iron and coke-oven industries, reports on study of spalling and chemical analysis, a recommendation for the withdrawal of the tentative test for slagging, and also that the Bureau of Standards prepare four standard samples for checking analysis of refractories. Committee D-5 on coal and coke submitted revisions of the standard methods of laboratory sampling and analysis of coal and coke and of the tentative definitions of terms relating to coal.

The research activities of the society were presented in the first annual report of committee E-9 on correlation of research. The report discussed the committee's conception of its work, explaining that it would not conduct research, and stated that its purpose was to see that significant general conclusions about materials and gaps in the knowledge of materials were brought to the attention of the society. At the same session of the meeting, committees E-1 on Methods of Testing and C-8 on Nomenclature and Definitions respectively submitted reports, and Dean Harvey, materials engineer of the Westinghouse Electric and Manufacturing Co., Pittsburgh, read a paper dealing with The Purchase of Materials on Specifications.

Investigation of Engineering Education

Summary of Reports of Committees Presented at the Schenectady Meeting of the S.P.E.E.

AT THE annual meeting of the Society for the Promotion of Engineering Education held in Schenectady, N. Y., June 17–20, there were presented reports from coöperating committees of the Society's Board of Investigation and Coördination which is working on a grant from the Carnegie Corporation and is making an introspective and comprehensive investigation of engineering education.

The preliminary reports presented cover the fact-finding portions of investigations carried on during the past academic year and are largely statistical in character. The coöperation of 114 colleges, practically all institutions which have any considerable number of engineering students, made it possible to obtain reliable data, and these have been summarized in the reports. To what extent the accumulation and interpretation of these data will aid education and the industries cannot be guessed at present, but educators, engineers, and those whose sons contemplate an engineering education will find the statistics interesting and instructive.

Engineering Students at Time of Entrance to College

That engineering students are in general of good racial extraction is confirmed by the fact that 96 per cent of the students, 74 per cent of their parents, and 61 per cent of their grandparents were born in the United States or Canada, and that 91 per cent of the grandparents were born either in the United States or Canada, or in countries in the northwestern part of Europe. These students come in the most part from homes of moderate means and limited cultural and educational background. It is interesting to note that 13 per cent of the fathers are college graduates and but 4 per cent engineers. These boys make their decisions to go to college and to take up courses in engineering early in life, usually before reaching the last year of high school. They are little influenced by advice and base their decisions on imperfect and faulty understandings of the careers they choose. As the committee rightly points out, this last is a most serious state of affairs and should be given careful consideration, while the facts adduced relative to cultural background demand careful planning of educational curricula.

Admissions and Eliminations

The paper requirements for admission to engineering schools seem to be practically uniform. Ninety-four per cent of the 116 institutions admit students on credentials from accredited high schools. Sixty-five per cent of the institutions specify what one-half of the entrance credits shall be, additional credits being optional over a wide field with an increasing tendency toward the physical and vocational. Standards set by the requirements for admission are in many cases nullified by the admission of "conditioned" students, mathematics and science representing by far the greatest number of conditions. Apparently nearly one-fifth of the entering students in 1924 were conditioned. Thirteen out of 65 schools reported the use of intelligence tests as part of the admission system, and 15 out of 64 the use of the personal interview. Eleven schools out of 70 reported a limitation of enrolment in engineering courses.

The status of eliminations reveals some surprising facts as shown by the following quotations from the report:

> The elimination rate is high and steadily growing higher. Graduation from engineering colleges in four years is a reality for less than 30 per cent of the students entering these colleges. Graduation at all is a possibility for less than 40 per cent of those entering.
>
> The rate of eliminations will continue to increase in direct proportion to the failure of the high schools to give training in essential preparatory work, in proportion to the increase of distracting influences in both high-school and college life outside the classroom, and in direct proportion to the lack of balance and stimulus in our engineering curricula.
>
> Approximately one-half of the total elimination takes place prior to the beginning of the sophomore year.
>
> The methods employed by a number of institutions to prevent or discourage the unprepared from entering their colleges of engineering have apparently reduced the percentages of eliminations and increased the quality of work which they are able to do.

The causes of eliminations indicate that more than fifty per cent are due to scholastic failure; and poor preparation or lack of ability accounts for almost 70 per cent of these failures.

Graduates and Former (Non-Graduate) Students

In studying the occupations of engineering graduates, a distinction was made between the older graduates who have passed through the somewhat unsettled first-five-year period and the more recent graduates. Of the more recent graduates there are 60 per cent in technical engineering, 11.4 per cent in research and teaching 15.2 per cent in administrative and sales work, 7.6 per cent in clerical or manual work, and 6 per cent in miscellaneous types of work. Of the older graduates, 23.3 per cent are in strictly technical work, 10.7 per cent in research and teaching, 61.8 per cent in ownership, executive, and administrative work, including sales, and 4.2 per cent in clerical and miscellaneous.

The first-year salary of the class of 1914 was $903 and of the class of 1924, $1430, but comparing these on a basis of the value of the dollar, it will be seen that the engineering graduate is just about holding his own. The earnings of recent graduates appear to increase at the rate of about $300 per year. The efforts of the colleges and of employees placed only 47 per cent of the graduates in their first jobs. The desire for the right sort of experience or opportunity influenced 73 per cent in the choice of the first job. Although the figures show a considerable and wasteful moving about during the first few years of adjustment, 73 per cent of the graduates are satisfied with their present jobs and 80 per cent with their prospects, while 96 per cent have a definite liking for engineering, and

98 per cent feel that they made no mistake in taking an engineering course.

Of significance are the opinions of graduates with reference to certain features of engineering education. The technical and scientific preparation for their work which they received in college was rated either good or excellent by 76.3 per cent. Scientific and technical subjects are held to be of greatest importance, followed in order by economic and cultural ones. The outstanding criticism by the graduate of engineering education seemed to be the lack of courses in business and economics. The opinion of 66.8 per cent that the objectives of engineering courses are to train the majority of men broadly for the general needs of industry and to train a few for the specific needs of engineering must be considered by those responsible for the setting up of engineering curricula. Among recent graduates the continuation of study by a majority of them is an encouraging indication of ambition and of the importance of education in advancement, but the part played by the colleges in the general program might very well be extended.

The chief reasons for leaving college are given by non-graduate former students as financial difficulty (26.3 per cent) and scholastic failure (22.9 per cent). The reasons for scholastic failure are given by 57.3 per cent as poor scholarship and lack of aptitude. Mathematics and science are reported by 78.9 per cent as being the subjects with which the greatest trouble was experienced.

COST OF ENGINEERING EDUCATION

The average cost per student per year for four classes of institutions is as follows:

Endowed universities	$582
Endowed polytechnic institutes	551
State universities	358
Land-grant colleges	298

These figures indicate that the total cost of engineering education per year in the United States is approximately $30,000,000, and that the total investment in engineering educational facilities in all institutions in the country approaches $300,000,000.

ENGINEERING TEACHING PERSONNEL

The investigation of the professional practice by teachers during the academic year indicates that this is permitted in 96 per cent of the 116 institutions reporting. Some institutions encourage such practice and some have definite arrangements to assist younger men in obtaining work. In general, members of staffs follow their own discretion as to what kind of work they do. From tables showing the supplementary income derived from such sources, it is evident that the total bulk of outside work does not present a serious problem. Regarding the use of laboratories for such work, practice differs. Some institutions do not permit such use, even when the work itself is permitted, and there are various methods of charging for materials, use of laboratory, overhead, etc.

Approximately 80 per cent of the colleges look upon the individual doing the work as solely responsible for results and in general avoid any official connection with industrial work, acting as public-service institions in placing their men and facilities at the disposal of the public.

There appears to be no general attempt on the part of engineering colleges to give instruction in the art of teaching members of their staffs.

Twenty per cent of the colleges use men regularly employed in industry as auxiliary teachers, but indicate the necessity of close correlation with regular courses and the danger of going beyond the depth of the student.

About 67 per cent of teachers of all ranks are obtained through promotion from the graduating classes and from the teaching ranks. There is a substantial interchange between schools and a notable proportion is obtained from engineering practice. For all grades of teachers and for all changes of position the annual turnover is about 10 per cent, and the actual annual loss of teachers by the institutions is about 6.75 per cent. Less than 5 per cent leave to enter practice, and only 1.09 per cent enter business. Out of more than 3000 teachers in 116 institutions, only 77 leaves of absence have been taken in five years.

An investigation of academic salary and supplementary income shows that 78.5 per cent of engineering teachers have sources of supplementary income, and a comparison of these is made with earnings of engineering graduates in practice. At the start the salaries of teachers exceed the earnings of graduates by a small amount. After the end of the first year the teachers earn steadily less than graduates in practice, until at the twentieth year after graduation the total earnings of teachers are but 76.5 per cent and the average academic salary only 61 per cent of the earnings of engineering graduates in practice.

Samuel Insull Heads National Museum of Engineering and Industry

AT THE Bankers Club, New York City, on Thursday, June 18, about sixty prominent industrials and engineers assembled for a luncheon in honor of Samuel Insull, incoming president of the National Museum of Engineering and Industry. The luncheon was presided over by Thomas Ewing, and with him were Thomas A. Edison, Judge Elbert Gary, Samuel Rea, and Alexander C. Humphreys.

Brief remarks were made by F. R. Low, past-president of the A.S.M.E., and by Alexander C. Humphreys, president of Stevens Institute and past-president of the Society. It was announced that $10,000,000 is necessary for the establishment of the museum, $1,000,000 of which is already promised.

Mr. Insull said that he had been led to accept the invitation to become president because of his firm conviction of the need for the museum. "We ought not," he said, "to have to go to London to see the first phonograph, and perhaps the first flying machine. The first direct-connected generator used at Menlo Park in the early 80's has been destroyed beyond hope of restoration.

"The fact that the Smithsonian Institution welcomes this movement," continued Mr. Insull, "is a sufficient warrant of its necessity. The museum needs the support and assistance of the great engineering societies, the manufacturing concerns, and the educational institutions of the country. These three elements working together ought to be able to carry the project to a successful conclusion.

"It is natural to say that the Government should provide the money, but if the Government provides the site and we find the money, Congress will doubtless take a helpful interest in an institution of such national importance when it becomes a going concern.

"It should be situated in Washington, and its natural resting place should be with the Smithsonian Institution. Nobody, no group of professional people, no manufacturer or industrial or trade organization should control it. Everybody should get together and help it."

Chicago–New York Air-Mail Service Starts

THE successful inauguration of overnight air mail between Chicago and New York on July 1, 1925, marks an important step in the development of the U. S. Mail Service with the valuable results that improved methods of communication and transport always bring. As the volume of ordinary mail and express traffic between these two cities is especially large, the establishment of a night air-route between them offers the best possible opportunity for the building up of a large volume of air express service on a commercial basis. In an interview on the occasion of the start of the first west-bound plane in the new service, Postmaster-General New expressed the view that the Chicago–New York night mail would not pay if operated for mail alone. Freight and express are necessary, and private companies equipped for this traffic could carry on contract as railroads do now. The Kelly Bill provides for such an arrangement.

The great spread of this country offers a splendid opportunity for high-speed air communication and transport. But without traffic volume, commercial success is not possible and subsidy is necessary. The word "subsidy" is anathema to the American public because it has generally meant a grant of money. But the pioneering that the Government does in establishing air-routes and operating them for the air-mail is of fundamental value to commercial projects and does not involve the payment of Government funds to private corporations. Therefore the establishment of the night route between Chicago and New York with its landing fields, weather stations and beacons may be looked upon as the first step in assisting a commercial line between the two cities.

The future of the airplane has often been considered in terms of the automobile which in twenty-five years has become a universally used vehicle. It is probable, however, that the airplane's immediate use will be as the tool of large transportation corporations that are able to provide a sufficient factor of financial and engineering safety during the period of growth. These companies must operate over developed routes for which the Government provides meteorological and beacon service similar to the lighthouses, buoys, and weather reports supplied for the marine shipper. The day when each family will have its air "flivver" is relatively remote.

The Chicago–New York mail service offers the best possibility for immediate commercial success and points to the prompt establishment of express transport over the same route.

New School of Aeronautics at New York University

ON JUNE 15 there was made public the announcement of the gift of $500,000 by Daniel Guggenheim to New York University for the establishment of a School of Aeronautics in the College of Engineering. In making the gift Mr. Guggenheim said that for some time he had been impressed with the need for placing aeronautics on the same educational plane that other branches of engineering enjoy. He pictured the great economic future for aeronautics and suggested that it would develop commercially as railroading had done.

Part of the gift is to be used for the purpose of erecting and equipping a building containing a wind tunnel, propeller laboratory, sand-testing laboratory, model shop, full-flight laboratory, power-plant laboratory and classrooms. The remainder of the fund will provide for the salaries of professors and assistants, and also for the maintenance of the building and equipment.

In accepting the gift, Chancellor Brown said that there were but three schools in the country specializing in aviation and aeronautics, that of New York University being the only one providing a full four-year undergraduate course, and that the new school would be called the Daniel Guggenheim School of Aeronautics.

Aeronautics has already received considerable attention at New York University under the direction of Prof. Collins P. Bliss, head of the department of mechanical engineering of the college of engineering, and Alexander Klemin, associate professor of aeronautics. The wind tunnel in which the models of the round-the-world flying boats were tested is now the property of the university, and with this Professor Klemin and his assistants have carried on much research. The 1925 class in aeronautics completed the designs of a small one-man airplane which is to be built by students and flown in the Pulitzer races. The model of this ship, built by undergraduates, has been fully tested in the wind tunnel and the characteristics of the plane have been determined. The men already graduated from this course have become actively engaged in aeronautics in various parts of the country.

The location of the school in New York City is of advantage to students of aeronautics because of the nearness of such places as Mitchel Field and Lakehurst, and also brings the facilities of the laboratories close to a great center of professional and commercial interests.

Bureau of Mines Transferred to the Department of Commerce

THE Bureau of Mines was transferred from the Department of the Interior to the Department of Commerce by executive order of the President on June 4, the actual transfer taking place on July 1. This change is in accordance with the program of Government reorganization recommended by the Joint Congressional Committee. In announcing the change, Secretary Work of the Department of the Interior pointed out that the transfer of the Bureau of Mines and the Division of Mineral Statistics is in line with the proposal to create in the Department of Commerce a division embracing the Government's activities in scientific and economic research to aid industry. The overlappings between the departments which now exist include research in the use of gasoline and lubricating oils in gas engines, studies relating to the qualities of fuel, service in domestic distribution and foreign trade in mineral products, statistics of mineral production, and research in the use of raw materials for the use of manufacturers.

The transfer of the Bureau of Mines to the Department of Commerce occurs simultaneously with the resignation of H. Foster Bain to accept the secretaryship of the American Institute of Mining and Metallurgical Engineers. Dorsey Lyon, who has frequently served as acting director of the Bureau of Mines during the extended absences of Director Bain in foreign countries, will serve until a new director is chosen.

Secretary Hoover has announced that no new policies will be formulated until there has been a full discussion with the organizations represented and interested in the work of the Bureau.

Discussing the transfer of the Bureau in the July issue of *Mining and Metallurgy*, Dr. Bain says:

> Up to now the major growth of the Bureau has been in the direction of service for the Government itself. In addition to its research work it tests the fuel for the government departments and even acts as a central fuel-purchasing agent for the government buildings in Washington. It enforces the regulations on the leased oil, gas, coal and potash public lands, assists the Indian Bureau in handling the mineral lands under its charge administers the operations on the naval petroleum reserves, and has just been charged with conservation and production of helium for the Army and Navy. All these duties are incidental to its main job of promoting efficiency and safety in mining, but while doing this work for the Government the Bureau staff has acquired experience and knowledge serviceable to the industry as a whole. The Government, in a sense, has been one of the Bureau's clients.
>
> Following transfer of the Bureau to the Department of Commerce by Executive Order, effective July 1, the Geological Survey rather than the Bureau of Mines will act for the Secretary of Interior in enforcing regulations on the leased lands. The other activities will be continued in the Bureau and in addition the Mineral Resources division of the Survey will join it. This brings together the statistical and technological work and should permit the preparation of an annual volume, with perhaps monthly advance summaries, that will be of even larger service to the industry than in the past. This is all the more true in that in the Bureau of Foreign and Domestic Commerce and in the Census Bureau there are activities that impinge on the same field. Adjustment of work and personnel will permit more work to be done with the same money and in this case, where so much remains to be done, that, rather than mere reduction of expenditure, is true economy.
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> In its metallurgical and technological work the Bureau of Mines will be brought into close neighborly relations to the Bureau of Standards. The latter has staff and laboratory equipment at Washington of the highest character. The Bureau of Mines' laboratories are in the field. Joint use and further specialization are clearly possible. The problems of the mineral industries can be brought closer together and the whole will profit greatly from the criticism and help of the specialists of both bureaus. Some shifting of boundaries and work is to be anticipated, but the two bureaus are complimentary to each other rather than duplicates.

Scott Medal Awarded to Charles H. Norton

CHARLES H. NORTON, consulting engineer of the Norton Co., Worcester, Mass., has been awarded the Scott Medal "in recognition of his contributions to the art of grinding in the invention of accurate grinding devices of high power." This award for exceptional achievement in the field of mechanical arts was conferred at the commencement exercises of the University of Pennsylvania, and was established by John Scott in a will dated April 2, 1916, the legacy being entrusted to the corporation of Philadelphia, and the award being made by the Board of Directors of City Trusts of Philadelphia. The advisory committee consisted of A. W. Goodspeed, secretary, representing the University of Pennsylvania; S. M. Vauclain, representing the American Philosophical Society; and H. H. Donaldson, W. B. Scott, and Theobald Smith, representing the National Academy of Sciences.

The inventions considered in the award of the medal include a number of improvements in grinding-machine design, such as the shape of the table, the mounting of the headstock and footstock, the mounting of the wheel slide and feed screw, the construction of a wheel slide without an adjustable gib, micrometer cross-feed for the wheel slide, and the "arc-of-a-circle" steady-rest shoe. Besides these, Mr. Norton has invented grinders for locomotive pistons, car axles, crankshafts and camshafts.

Mr. Norton became a member of the A.S.M.E. in 1913, and the Transactions of the Society contain three papers by him on grinding as well as several discussions.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Employees' Representation in Steel Works

EMPLOYEES' REPRESENTATION IN STEEL WORKS. By Ben M. Selekman. Russell Sage Foundation, New York, 1924. Cloth, 5¼ × 7¾ in., 293 pp., $1.50.

THIS book is a report by Mr. Ben M. Selekman of a study of the industrial representation plan of the Minnequa Steel Works of the Colorado Fuel and Iron Company, which study was made for the Russell Sage Foundation. There is also a foreword by Mary Van Kleeck, director of industrial studies for the Russell Sage Foundation, which states that this is one of a number of similar studies which the Foundation is carrying forward. There is also an introductory synopsis giving a summary of the investigation and the principal findings of the investigators.

The book is of some importance since it gives an account of the establishment of employee representation in the mines of the Colorado Fuel and Iron Company, and in the steel mills of this company in 1916, and particularly as these were among the early experiments with this form of coöperation between employer an employee. The larger part of the book deals with the plan as introduced into the steel mills. It is to be noted that the plan was introduced by the management voluntarily and at a time when there were no labor troubles existent at the works.

The first chapters of the book give an account of working conditions in steel works and of the inception and organization of the plan of representation. There is nothing particularly noteworthy in this plan as it follows the general tenor of all such plans in so far as the election of the representatives, the machinery for adjusting grievances, bettering working conditions, etc., are concerned. Chapter IV contains an interesting account of the influence exerted by the plan upon securing an eight-hour day.

In 1919 the men at the Minnequa Steel Works went out on strike as a part of the national strike of steel workers organized by the unions affiliated with the American Federation of Labor. This strike was lost by the workers and the industrial representation plan was restored and continued.

The last chapter, Accomplishments and Limitations of Employees' Representation, is perhaps the most important one in the book, since it deals with results actually accomplished and with the defects of the plan. The plan is credited with being of great aid in securing the eight-hour day, with making it possible for the workers to participate in the revision of wages, and with adding considerably to the security of employment.

On the other hand, it appears from the report that the closer personal relations which the management had hoped to establish were not forthcoming and that the attitude of foreman and other officials toward the workers was not greatly changed by the new methods. The workers complained to the investigators not only about this lack of coöperation but criticized also the failure to recognize seniority of service. They further complained that they had not been consulted as fully as they should have been, and the investigators appear to take this view also, as the report states. To quote:

> The written plan provided for the annual election of employees' representatives from fellow-workers employed in the steel plant. The president of the company administered the plan.... The written plan did not give the workers a voice in the management nor did it impose upon company officials the necessity of consulting the workers on any changes affecting the interests of employees except when such changes were to be made following the introduction of new wage rates or working conditions by the competitors of the company.

If these statements are true, it would appear that there were definite limitations to the voice of the workers and that this experiment did not visualize industrial democracy as advocated by some later industrial reformers, and as illustrated by later experiments along this line. The summary at the end of the book is of interest in this respect. It reads as follows:

> At present, then, the scope of the industrial representation plan is seriously limited. It is true that in an industry so devoid of any tradition concerning representation of the workers as the steel industry is, the industrial representation plan marks a distinct step in advance toward recognizing the workers' aspirations; for under the plan the men of the Minnequa Steel Works secured such important gains as the actual eight-hour day, an opportunity to participate in revising wage scales, a method of presenting and discussing grievances, and a greater degree of security in their jobs through enjoying the right to appeal to higher officials against the decisions of foremen and superintendents. When one looks at these accomplishments and then considers the methods of the United States Steel Corporation, one must conclude that at least in one small segment of the industry the wage earners have been afforded an opportunity to have a voice in determining conditions under which they must work. Nevertheless, until the men throughout the industry as a whole secure adequate and effective representation in determining wage standards, those employed in any one plant, such as the Minnequa Steel Works, are bound to be dissatisfied. Every week the Minnequa workers are reminded by their pay envelopes that the scope of their representation does not give them an effective share in determining their own earnings, and none whatever in determining those of their fellow-workers in the steel industry at large.

Industrial democracy no doubt has many limitations and this report shows clearly what some of these limitations are. Workers can express intelligent ideas concerning wages, working conditions, shop conditions, shop processes, etc., but as yet there has been no experience with industrial democracy that would indicate that workmen, as a rule, can take an intelligent part in the financial and economic problems of management.

It should be remembered that this report has been made by investigators who obtained most of their information by questioning the workers. There is always a certain amount of doubt as to the accuracy of such information, especially when obtained in times of industrial disturbances. It would be interesting to hear the other side of the story as told by the management of the Colorado Fuel and Iron Company.

DEXTER S. KIMBALL.[1]

Standard Specifications and Methods of Test for Materials

STANDARD SPECIFICATIONS AND METHODS OF TEST MATERIALS. By C. L. Warwick. American Society for Testing Materials, 1925. Paper, 6¾ × 9¾ in., 19 pp.

A PAPER presented at the First Pan-American Conference on Uniformity of Specifications, Lima, Peru, December 23, 1924, and reprinted with permission of the Director General of the Pan-American Union. Referred to in Report on the First Pan-American Conference on Uniformity of Specifications, published by the Inter-American High Commission, pp. 46 and 101.

[1] Dean, College of Engineering, Cornell University, Ithaca, N. Y. Past-President, A.S.M.E.

The paper describes the development in the United States of standard specifications and methods of test for materials through the work of the American Society for Testing Materials. The early developments in advancing the knowledge of engineering materials and methods of testing materials are referred to. Then follows a description of the standardization work of the society, touching upon the personnel of the committees, the principle of bringing producers and consumers of materials together on an equal footing in committees charged with the development of commercial standards for materials, the different ways in which standardization problems present themselves, the necessity of establishing standard methods of test and a standard nomenclature before specifications can be prepared, and finally the considerations that enter into the fixing of specification requirements.

There is some mention of the 400 standard and tentative specifications and methods of test that have been formulated by the society, and a discussion of the use of these standards in the industries.

After pointing out the benefits of standard specifications to the producers and consumers of materials, the industrial and economic significance of standard specifications for materials is briefly summed up in the statement that by facilitating quantity production of material of known quality and reliability, they help to make possible economies in the manufacture, distribution, and use of material that are reflected in the profits of business and reduce to some extent the elements of risk.

Mention is made of the important role of the American Engineering Standards Committee in coördinating engineering and industrial standardization work throughout the United States.

The paper closes with a brief discussion of international standards for materials.

Books Received in the Library

BAU GROSSER ELEKTRIZITÄTSWERKE. By G. Klingenberg. Second edition. Julius Springer, Berlin, 1924. Boards, 8 × 12 in., 608 pp., illus., diagrams, plates, 45 gold marks.

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LA COMPTABILITÉ MODERNE. By J. Dumarchey. Gauthier-Villars et Cie., Paris, 1925. Paper, 6 × 10 in., 372 pp., 40 francs.

The object set before him by the author of this work is the establishment of a rational system of accounting which will rest on a sound philosophic and scientific basis and also meet technical requirements. In his discussion, he has made extensive developments of various entirely new theories of accounting, he states. These theories are set forth at length and finally condensed into simple formulas that can be readily applied in practice.

CONCERNING THE NATURE OF THINGS. By Sir William Bragg. Harper & Bros., New York, 1925. Cloth, 6 × 8 in., 250 pp., illus., $3.

Contents: Atoms of which things are made; nature of gases; nature of liquids; nature of crystals—diamond; nature of crystals—ice and snow; nature of crystals—metals; note.

In 1825 the Royal Institution instituted a series of Juvenile Lectures which have been given annually since that time by many famous men of science and have set a high standard as models of popular exposition. The present volume is an outgrowth of the course of lectures given by Sir William Bragg in 1923–24. It treats of the structure of the atom and of the molecular forms exhibited by matter in various states, bringing to the reader the most recent discoveries and modern views, and illustrating them with many novel experiments.

COURS D'AVIATION. By A. Desaleux. Gauthier-Villars & Cie., Paris, 1925. Paper, 7 × 10 in., 246 pp., diagrams, 35 francs.

A textbook for beginners, based on experience as an instructor and as a flier. Covers the elements of aeronautics, including aerodynamics and its application to airplanes, the construction of airplanes, instruments, operation of motors, use of maps and the principles of meteorology.

ECONOMICS OF OUR PATENT SYSTEM. By Floyd L. Vaughan. Macmillan Co., New York, 1925. Cloth, 5 × 8 in., 288 pp., $2.50.

The author says that the patent system has been bent to purposes and has facilitated results never intended or expected by the framers of the Constitution and the patent system. Patents have been used to defeat the object of the anti-trust laws, to restrain trade, and to form industrial monopolies. They have been used as a pretext for unfair methods of competition and, to this end, many have been suppressed. Various evils have discouraged invention. The social and economic cost of our patent system—industrial monopolies, suppression of patents, discouragement of invention, and economic waste—constitutes a tremendous liability in appraising its net utility. This cost is the subject of the greater part of this book. The final chapter suggests a number of remedies for the situation.

ELEMENTS OF RAILWAY ECONOMICS. By Sir William M. Acworth. New edition, revised and enlarged. Clarendon Press, Oxford, 1924. Cloth, 5 × 7 in., 216 pp., $1.20.

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ENTWERFEN IM KRANBAU. By Rudolf Krell, with a supplement, Elektrische Kranausrüstungen, by Christian Ritz. R. Oldenbourg, Munich and Berlin, 1925. 2 vols.: vol. 1, text; vol. 2, plates. Cloth, 9 × 13 in., 32 marks.

This work is not intended so much for use as a textbook on crane design as to be a handbook for designers. The book discusses the various elements of cranes—keys, bolts, rivets, chains, ropes, drums, tackle, bearings, axles, brakes, gearing, etc.—giving the necessary formulas and numerical data, with diagrams from which the proper dimensions for ordinary cases may be obtained at once. The atlas contains over one thousand sketches of crane details and many useful graphs. In the appendix are a number of examples, fully solved, which show the use of these tables.

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Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Employees' Representation in Steel Works

EMPLOYEES' REPRESENTATION IN STEEL WORKS. By Ben M. Selekman. Russell Sage Foundation, New York, 1924. Cloth, 5¼ × 7¾ in., 293 pp., $1.50.

THIS book is a report by Mr. Ben M. Selekman of a study of the industrial representation plan of the Minnequa Steel Works of the Colorado Fuel and Iron Company, which study was made for the Russell Sage Foundation. There is also a foreword by Mary Van Kleeck, director of industrial studies for the Russell Sage Foundation, which states that this is one of a number of similar studies which the Foundation is carrying forward. There is also an introductory synopsis giving a summary of the investigation and the principal findings of the investigators.

The book is of some importance since it gives an account of the establishment of employee representation in the mines of the Colorado Fuel and Iron Company, and in the steel mills of this company in 1916, and particularly as these were among the early experiments with this form of coöperation between employer an employee. The larger part of the book deals with the plan as introduced into the steel mills. It is to be noted that the plan was introduced by the management voluntarily and at a time when there were no labor troubles existent at the works.

The first chapters of the book give an account of working conditions in steel works and of the inception and organization of the plan of representation. There is nothing particularly noteworthy in this plan as it follows the general tenor of all such plans in so far as the election of the representatives, the machinery for adjusting grievances, bettering working conditions, etc., are concerned. Chapter IV contains an interesting account of the influence exerted by the plan upon securing an eight-hour day.

In 1919 the men at the Minnequa Steel Works went out on strike as a part of the national strike of steel workers organized by the unions affiliated with the American Federation of Labor. This strike was lost by the workers and the industrial representation plan was restored and continued.

The last chapter, Accomplishments and Limitations of Employees' Representation, is perhaps the most important one in the book, since it deals with results actually accomplished and with the defects of the plan. The plan is credited with being of great aid in securing the eight-hour day, with making it possible for the workers to participate in the revision of wages, and with adding considerably to the security of employment.

On the other hand, it appears from the report that the closer personal relations which the management had hoped to establish were not forthcoming and that the attitude of foreman and other officials toward the workers was not greatly changed by the new methods. The workers complained to the investigators not only about this lack of coöperation but criticized also the failure to recognize seniority of service. They further complained that they had not been consulted as fully as they should have been, and the investigators appear to take this view also, as the report states. To quote:

> The written plan provided for the annual election of employees' representatives from fellow-workers employed in the steel plant. The president of the company administered the plan.... The written plan did not give the workers a voice in the management nor did it impose upon company officials the necessity of consulting the workers on any changes affecting the interests of employees except when such changes were to be made following the introduction of new wage rates or working conditions by the competitors of the company.

If these statements are true, it would appear that there were definite limitations to the voice of the workers and that this experiment did not visualize industrial democracy as advocated by some later industrial reformers, and as illustrated by later experiments along this line. The summary at the end of the book is of interest in this respect. It reads as follows:

> At present, then, the scope of the industrial representation plan is seriously limited. It is true that in an industry so devoid of any tradition concerning representation of the workers as the steel industry is, the industrial representation plan marks a distinct step in advance toward recognizing the workers' aspirations; for under the plan the men of the Minnequa Steel Works secured such important gains as the actual eight-hour day, an opportunity to participate in revising wage scales, a method of presenting and discussing grievances, and a greater degree of security in their jobs through enjoying the right to appeal to higher officials against the decisions of foremen and superintendents. When one looks at these accomplishments and then considers the methods of the United States Steel Corporation, one must conclude that at least in one small segment of the industry the wage earners have been afforded an opportunity to have a voice in determining conditions under which they must work. Nevertheless, until the men throughout the industry as a whole secure adequate and effective representation in determining wage standards, those employed in any one plant, such as the Minnequa Steel Works, are bound to be dissatisfied. Every week the Minnequa workers are reminded by their pay envelopes that the scope of their representation does not give them an effective share in determining their own earnings, and none whatever in determining those of their fellow-workers in the steel industry at large.

Industrial democracy no doubt has many limitations and this report shows clearly what some of these limitations are. Workers can express intelligent ideas concerning wages, working conditions, shop conditions, shop processes, etc., but as yet there has been no experience with industrial democracy that would indicate that workmen, as a rule, can take an intelligent part in the financial and economic problems of management.

It should be remembered that this report has been made by investigators who obtained most of their information by questioning the workers. There is always a certain amount of doubt as to the accuracy of such information, especially when obtained in times of industrial disturbances. It would be interesting to hear the other side of the story as told by the management of the Colorado Fuel and Iron Company.

DEXTER S. KIMBALL.[1]

Standard Specifications and Methods of Test for Materials

STANDARD SPECIFICATIONS AND METHODS OF TEST MATERIALS. By C. L. Warwick. American Society for Testing Materials, 1925. Paper, 6¾ × 9¾ in., 19 pp.

A PAPER presented at the First Pan-American Conference on Uniformity of Specifications, Lima, Peru, December 23, 1924, and reprinted with permission of the Director General of the Pan-American Union. Referred to in Report on the First Pan-American Conference on Uniformity of Specifications, published by the Inter-American High Commission, pp. 46 and 101.

[1] Dean, College of Engineering, Cornell University, Ithaca, N. Y. Past-President, A.S.M.E.

The paper describes the development in the United States of standard specifications and methods of test for materials through the work of the American Society for Testing Materials. The early developments in advancing the knowledge of engineering materials and methods of testing materials are referred to. Then follows a description of the standardization work of the society, touching upon the personnel of the committees, the principle of bringing producers and consumers of materials together on an equal footing in committees charged with the development of commercial standards for materials, the different ways in which standardization problems present themselves, the necessity of establishing standard methods of test and a standard nomenclature before specifications can be prepared, and finally the considerations that enter into the fixing of specification requirements.

There is some mention of the 400 standard and tentative specifications and methods of test that have been formulated by the society, and a discussion of the use of these standards in the industries.

After pointing out the benefits of standard specifications to the producers and consumers of materials, the industrial and economic significance of standard specifications for materials is briefly summed up in the statement that by facilitating quantity production of material of known quality and reliability, they help to make possible economies in the manufacture, distribution, and use of material that are reflected in the profits of business and reduce to some extent the elements of risk.

Mention is made of the important role of the American Engineering Standards Committee in coördinating engineering and industrial standardization work throughout the United States.

The paper closes with a brief discussion of international standards for materials.

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FRANZ REULEAUX UND SEINE KINEMATIK. By Carl Weihe. Julius Springer, Berlin, 1925. Boards, 5 × 8 in., 100 pp., portraits, 3 gold marks.

An appreciative sketch of the man and his work, by a former pupil. The main events in Reuleaux's career as an investigator and teacher are considered, and a chapter given to a consideration of the philosophy and influence of his conception of kinematics. Reuleaux's important paper, Kultur und Technik, is republished and there is a bibliography of his writings.

FRICTION CLUTCHES. By R. Waring-Brown. Isaac Pitman & Sons, London and New York, 1924. Cloth, 5 × 7 in., 124 pp., illus., tables, $1.50.

A concise yet comprehensive presentation of the principles involved in the design and operation of friction clutches. Many recent devices are described and modern applications to many classes of machinery are shown.

HISTORY OF MATHEMATICS. By David Eugene Smith. Ginn & Co., Boston and New York, 1923–1925. Cloth, 6 × 9 in., 2 vols., illus., facsimiles, vol. 1, $4; vol. 2, $4.40.

These two volumes contain a readable account of the development of elementary mathematics, through the first steps in calculus, from the earliest times down to the present. The story is illustrated with many portraits and with diagrams and pictures from old mathematical books. Ample bibliographical data are provided. The work is planned to present the subject from two distinct standpoints. In volume one the growth of mathematics is presented by chronological periods, with due consideration to racial achievements. In volume two the evolution of certain important topics is described. While intended primarily for teachers and student of mathematics, the book will undoubtedly interest many engineers and others who use mathematics.

HOUSEHOLD REFRIGERATION. By H. B. Hull. Nickerson & Collins Co., Chicago, 1924. Cloth, 6 × 9 in., 328 pp., illus., tables, $3.50.

A treatise covering methods of household refrigeration by ice and by refrigerating machines. The theory of refrigeration and the properties of the suitable refrigerants are set forth, heat transfer is discussed, and there are descriptions of many types and constructions of refrigerating machines and refrigerators. Chapters are devoted to the operation of refrigerators, to testing methods, and to the preservation of foods in the home. Many tables of numerical data used by engineers are included. This is the first book on this subject, the author says.

INDUSTRIAL POISONS IN THE UNITED STATES. By Alice Hamilton. Macmillan Co., New York, 1925. Cloth, 6 × 9 in., 590 pp., $5.

The author, who is assistant professor of industrial medicine at the Harvard Medical School, has brought together a vast amount of information on the diseases of various trades and on the poisonous effects of various substances used in industry. Much of the information is the result of extended personal investigations.

LOCOMOTIVE CYCLOPEDIA OF AMERICAN PRACTICE. Seventh edition, 1925. Compiled and edited for the American Railway Association, Division V. Mechanical, by Roy V. Wright and Robert C. Augur. Simmons-Boardman Publishing Co., New York, 1925. Cloth, 9 × 12 in., 1130 pp., illus., diagrams $8.

The seventh edition retains the arrangement of matter adopted in 1922, by which all matter relating to each specific subject is grouped in a single chapter. The division into chapters, however, has been improved and the arrangement changed to a more convenient one. The new edition includes the new designs of locomotives and appliances which have been developed in recent years. Like its predecessors, it gives the specifications of the American Railway Association, a wealth of drawings of locomotives, details and appliances, general illustrations, and descriptive matter issued by manufacturers.

MAN AND HIS AFFAIRS FROM THE ENGINEERING POINT OF VIEW. By Walter N. Polakov. Williams & Wilkins Co., Baltimore, 1925. Cloth, 5 × 8 in., 233 pp., $2.50.

The author advocates the use of the mathematical method in the study of man and his affairs. Heretofore, he says, man has either been outlawed from nature and speculated about in metaphysical and theological terms, or else the broad subject has been lost in a maze of psycho-physiological details. The new point of view of the universe, man included, makes him a part of nature, susceptible to scientific study without resort to metaphysics. The book is intended to present this new viewpoint to the general reader and to indicate some of the advantages that it promises.

MANAGERIAL ACCOUNTING, vol. 1. By James O. McKinsey. University of Chicago Press, Chicago, 1924. Cloth, 5 × 8 in., 655 pp., forms, $4.

This book approaches accounting from a new viewpoint, that of the business executive. It is intended to give him a basic knowledge of accounting, not as an end in itself, but as an important means for the solution of business problems. It discusses the need and nature of standards and records in business, organization for the control of records and standards, administrative reports, and the control of sales, purchases, traffic, and production. The author is a professor in the School of Commerce and Administration at the University of Chicago.

MECHANICS OF MACHINERY: KINEMATICS AND DYNAMICS. By Robert C. Heck. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 550 pp., diagrams, tables, $5.

This second volume of Professor Heck's textbook is devoted to the study of motions and forces within machines; with the previous volume on machine design the work forms a fairly complete treatise on these important divisions of the scientific background of mechanical engineering. The book includes something on all important subdivisions of the subject and gives a consistent, correlated treatment of their various parts. It is arranged so that courses of varying length and content may be selected. Certain topics, such as the modern theory of lubrication, Stribeck's work on ball bearings, and Barth's theory of belt action, have not previously been put into textbook shape, the author states.

MODERN GAGING PRACTICE. By Albert A. Dowd and Frank W. Curtis. Engineering Magazine Co., New York, 1925. (Industrial Management Library.) Cloth, 6 × 9 in., 280 pp., illus., tables, $3.

A descriptive work upon the limit system, gaging, and inspection as used in interchangeable manufacture. The book is intended to acquaint laymen and novices with these matters and therefore omits highly technical descriptions.

MODERNE METALLKUNDE IN THEORIE UND PRAXIS. By J. Czochralski. Julius Springer, Berlin, 1924. Boards, 5 × 8 in., 292 pp., illus., diagrams, tables, 12 gold marks.

Among the topics discussed are the chief varieties of binary-alloy solidification diagrams, the solidification diagrams of the commercial alloys, the principal varieties of phenomena produced by etching, methods of etching and the importance of molecular structure in foundry practice. Attention is also given to the crystallographic phenomena that accompany cold-working, recrystallization diagrams and reactions, the bedding theory and X-ray examinations, the principles of hardening processes, the phenomena of inner flow and their importance in working metals. The book is not intended as a systematic textbook of metallography, but rather as a concise presentation of modern theories, to be used as a supplement to the classic treatises on metallurgy.

PATTERN MAKING. By Joseph G. Horner. Fifth edition, revised and enlarged. Crosby Lockwood & Son, London, 1925. Cloth, 6 × 9 in., 437 pp., illus., tables, 18 shillings.

The new edition of this well-known work has been thoroughly revised and rearranged, and much new matter has been added. The book covers a large field, ranging from elementary constructions to the pattern work required for gearwheels and for machine molding.

PERSONAL LEADERSHIP IN INDUSTRY. By David R. Craig and W. W. Charters. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 8 in., 295 pp., $2.50.

This book is concerned, not with the question of personnel administration, but with the important problem of the supervision of subordinates. It is intended to make available the experience of successful executives in handling this individual problem. By a study of the methods used by successful executives, the authors

have determined the qualities and traits of character involved in effective personal leadership in industry. These are defined and suggestions made to assist in developing them.

PERSONNEL ADMINISTRATION: a Bibliography. By William H. Rossi and Dianna I. Powers Rossi. Williams & Wilkins Company, Baltimore, 1925. (Human relations series.) Cloth, 6 × 8 in., 365 pp., $5.

A bibliography of books and articles in periodicals which appeared during the years 1919–1923. Makes no claim to completeness, but 2700 titles are entered. These are grouped under a simple classification which facilitates reference to the literature on any topic. The bibliography is restricted, apparently, to publications in the English language.

PORT DEVELOPMENT. By Roy S. MacElwee. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 456 pp., illus., maps. tables, $5.

"Port Development" is concerned primarily with questions of government, administration, traffic, and solicitation; in other words, with those problems other than mere physical terminal facilities which are fundamental in the competitive ability of a port. In the first section the author discusses the general value of port development to the nation and the port city, the effect of government laws, port administration, and freight solicitation. Section two compares the statistics and physical features of many of the world's ports and discusses the advantages of location. The third section analyzes the comparative traffic advantages of ports, including rates, costs, and services. The fourth section treats of free ports and their advantages in port development.

PREPARATION OF SCIENTIFIC AND TECHNICAL PAPERS. By Sam F. Trelease and Emma S. Yule. Williams & Wilkins Co., Baltimore, 1925. Cloth, 5 × 8 in., 113 pp., $1.50.

A manual of style for the assistance of those who are writing articles on scientific and technical subjects, theses, reports, etc. The book discusses such matters as the collection of data, arrangement of subject-matter, preparation of manuscript, proof reading, illustrations, etc. There is much practical information on questions of grammar, style, footnotes, etc., all presented with conciseness and clearness. The book should be distinctly helpful to any writer.

PRINCIPLES OF MACHINE DESIGN. By C. A. Norman. Macmillan Company, New York, 1925. (Engineering Science Series.) Cloth, 6 × 9 in., 710 pp., illus., diagrams, tables, $6.50.

In this textbook the author, while supplying practically valid rules and good patterns for the design of machines, tries also to introduce a broader vision of engineering in its social relations. He endeavors to give the student some idea of how engineering advance is achieved, of the struggles and controversies involved, of the sifting of evidence, of the correlation of mathematical and experimental fact with practical experience; and to train him to reason soundly on engineering problems.

SHOP AND OFFICE FORMS, THEIR DESIGN AND USE. By Wallace Clark. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 139 pp., $2.50.

The author treats of the forms for shop and office records and presents the results of his own experience in designing and handling them. The technique of form design occupies the first part of the book. This is followed by chapters showing the relation of forms to storeskeeping, production, cost keeping, maintenance, sales, estimating, and purchasing. The final section treats of general administrative features connected with forms.

PRODUCTION AND MEASUREMENT OF LOW PRESSURES. By F. H. Newman. D. Van Nostrand Co., New York, 1925. Cloth, 5 × 8 in., 192 pp., diagrams, tables, $5.

Although high-vacuum technique occupies an important position in engineering and physics today, it has been difficult to obtain information on the subject because the data are scattered in many publications. The present volume is intended to lessen the difficulties of workers in this field by providing an account of the more important instruments and devices used in high-vacuum work.

After an introductory chapter the varieties of pumps—oil, mercury, high-speed molecular and mercury vapor—are described in detail. Other processes for removing gases—by sorption, chemical, thermal, and electrical—are discussed. There are chapters on manometers and on procedure in exhausting vessels, and appendices of useful data concerning vapor pressures, pump speeds, etc.

PSYCHOLOGY OF SELECTING MEN. By Donald A. Laird. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 274 pp., illus., diagrams, $3.

The purpose of this book is to set forth, in a non-technical way, a technical account of the fundamental considerations in selecting men. The author first surveys critically traditional methods of selection, by letters of application, photographs, interviews, recommendations, etc. From these he proceeds to a description of the scientific method of selection and to a formulation of the principles to be followed by employees in the use of this method. Dr. Colgate is associate professor of psychology at Colgate University.

STRENGTH OF MATERIALS. By Edward R. Maurer and Morton O. Withey. John Wiley & Sons, New York, 1925. Cloth, 6 × 9 in., 382 pp., illus., diagrams, tables, $3.50.

Intended primarily as a textbook for the authors' students in the University of Wisconsin, this book covers the ground usually included in undergraduate courses. The authors have aimed at a teachable book. Particular attention has been given to definitions, demonstrations, proofs, solved illustrative examples, and problems.

THEORY OF RELATIVITY. By L. Silberstein. Second edition, enlarged. Macmillan & Co., London, 1924. Cloth, 6 × 9 in., 563 pp., $6.

The first ten chapters of this volume are practically a reprint of the first edition. They trace the connection of the theories and ideas that preceded the theory of relativity to this modern view and expound what is now called special or restricted theory. To these chapters have been added six new ones and a number of miscellaneous notes, which almost double the original size of the work. They contain a systematic exposition of the theory of general relativity and gravitation and of relativistic cosmology. The book is based on courses of lectures given at University College, London, the University of Toronto, and the University of Chicago.

VAUBAN, BUILDER OF FORTRESSES. By Daniel Halévy. Lincoln Macveagh, The Dial Press, New York, 1925. Cloth, 6 × 9 in., 256 pp., portrait, $2.75.

A vivid relation of what is known about the life of the most celebrated of military engineers. Traces his career from its beginnings under Condé, in 1651 to his death in 1706, during which time he built 160 fortresses and conducted forty sieges. This biography does not attempt to discuss the technical side of Vauban's work but to emphasize the important part that he played in the unification and defense of France.

VERSUCHE MIT PLATTENBALKEN. Vol. 1, Ausgeführt im Versuchs- und Materialprüfungsamt der Technischen Hochschule Dresden . . . . edited by Dipl.-Ing. Amos. Wilhelm Ernst & Sohn, Berlin, 1924. Paper, 7 × 10 in., 57 pp., illus., diagrams, tables, $1.20.

Records the methods used and the results obtained in an investigation of reinforced concrete T-beams carried on from 1911 to 1913 in the Testing Laboratory of the Dresden Technical High School. The investigation was planned to determine the conditions under which such beams could safely be used in railroad structures and to determine the effect of repeated intermittent loading, of smoke and steam, upon their strength. Tests were made with beams under constant load, exposed to the weather and to smoke and steam; and of beams under rapidly repeated loads, exposed to the air and to flue gases. Complete results of the tests are given in detail.

WORKMEN'S COMPENSATION INSURANCE, INCLUDING EMPLOYERS' LIABILITY INSURANCE. By G. F. Michelbacher and Thomas M. Nial. McGraw-Hill Book Co., 1925. Cloth, 6 × 8 in., 503 pp., illus., $4.

After a presentation of the problem of industrial injuries and their prevention, and of the development of workmen's compensation here and abroad, the authors give a detailed exposition of the principles and practices of the business of workmen's compensation insurance and employers' liability insurance. The book is based on lectures given at Columbia University and on the experience of the authors with the National Bureau of Casualty and Surety Underwriters.